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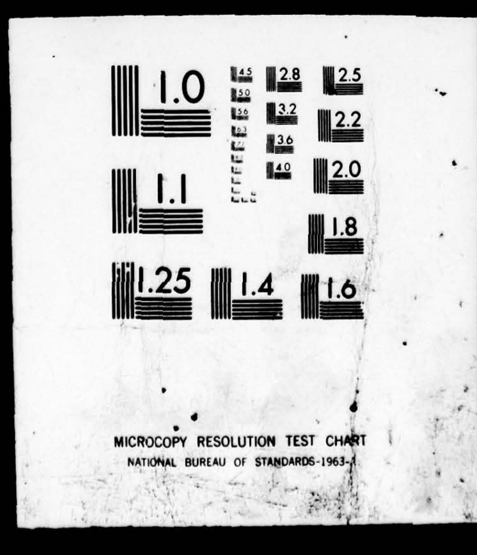

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6 COMPILATION OF DATA RELEVANT TO NUCLEAR PUMPED LASERS.

VOLUME V.

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Volume III contains pages 893 through 1348;
Volume IV contains pages 1349 through 1916;
Volume V contains pages 1917 through 2401

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Excitation	Laser pumping mechanisms	High energy electron beams
Ionization	Heavy nuclides	High energy ion beams
	Light nuclides	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This volume, and Volumes III and IV, contain a compilation of data relevant to nuclear pumped lasers and are part of a series on atomic and molecular data for gas laser research and development. The first two volumes, contained "Compilation of Data Relevant to Rare Gas-Rare Gas and Rare Gas-Monohalide Excimer Lasers" by E. W. McDaniel, M. R. Flannery, H. W. Ellis, F. L. Eisele, W. Pope, and T. G. Roberts.

ABSTRACT (CONTINUED)

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ABSTRACT (CONCLUDED)

Volumes III, IV, and V (presented here) contain data on many different species of atoms, molecules, and ions: a large fraction of them are already of direct interest in laser media; many more may become important in the future. These volumes cover all of the subjects treated in Vols. I and II; one difference is that now secondary electron energy spectra are discussed in a separate chapter. A chapter on nuclear data has also been added.

A species index for all five volumes will be published separately.

ACKNOWLEDGMENTS FOR VOLUME V (CHAPTERS D - J)

On the subject of photoionization we wish to express our gratitude to Dr. Joe Berkowitz of Argonne National Laboratory for providing us access to his monograph prior to publication, as well as for allowing us to use previously unpublished data.

We appreciate the generosity of Professor L. G. H. Huxley and Dr. R. W. Crompton of the Australian National University in allowing us to use figures from their excellent book on electron transport phenomena. Dr. A. V. Phelps was also extremely helpful during preparation of our section on electron transport.

Dr. J. F. Ziegler of IBM and Drs. S. Datz, G. S. Hurst, and M. G. Payne supplied useful advice on the subject of particle penetration in gases.

For their help on the secondary electron spectra chapter, we are grateful to a number of people for providing us with unpublished data as well as data tables and original figures: Dr. L. H. Toburen of Battelle Northwest; Professor M. E. Rudd of the University of Nebraska; Dr. N. Stolterfoht of the Hahn-Meitner Institut; Dr. N. Oda of the Tokyo Institute of Technology; and Dr. D. A. Vroom of the IRT Corporation.

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D. PHOTON COLLISION PROCESSES IN GASES

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General References

B. D. Buckley (Ed.), Photoionization of Atoms and Molecules, Daresbury Laboratory Report DL/SCI/R11 (Atomic and Molecular), 1978.

U. Fano and J. W. Cooper, "The Spectral Distribution of Oscillator Strengths," Rev. Mod. Phys. 40, 441 (1968).

F. J. Wuilleumier, Ed., Photoionization and Other Probes of Many-Electron Interactions (Plenum, N.Y., 1976).

S. T. Manson, "Atomic Photoelectron Spectroscopy, Part I," in L. Marton (Ed.), Advances in Electronics and Electron Physics 41, 73 (Academic, N.Y. 1976).

S. T. Manson, "Atomic Photoelectron Spectroscopy, Part II," in L. Marton (Ed.), Advances in Electronics and Electron Physics 44, 1 (Academic, N.Y. 1977).

G. V. Marr, Photoionization Processes in Gases (Academic, N.Y., 1967).

G. V. Marr, I. H. Munro, and J. C. C. Sharp, Synchrotron Radiation: A Bibliography, Daresbury Nuclear Physics Laboratory Report DNPL/R24, 1972; Supplement August 1972 to February 1974, Daresbury Nuclear Physics Laboratory Technical Memorandum DL/TM 127, 1974.

J. A. R. Samson, "The Measurement of the Photoionization Cross Sections of the Atomic Gases" in D. R. Bates and I. Estermann (Eds.), Advances in Atomic and Molecular Physics, 2, 177 (Academic, N.Y., 1966).

G. V. Marr and J. B. West, "Absolute Photoionization Cross Section Tables for Helium, Neon, Argon and Krypton in the VuV Spectral Regions," Atomic Data and Nuclear Data Tables 18, 497 (1976).

R. D. Hudson and L. J. Kieffer, "Compilation of Atomic Ultraviolet Photoabsorption Cross Sections for Wavelengths between 3000 and 10 Å," Atomic Data 2, 205 (1971).

L. J. Kieffer, "Bibliography of Low-Energy Electron and Photon Cross Section Data (through December, 1974)", NBS Special Publication 426, U.S. Department of Commerce/National Bureau of Standards (1976).

J. W. Gallagher, "Bibliography of Free-Free Transitions in Atoms and Molecules," JILA Information Center Report No. 16, Joint Institute for Laboratory Astrophysics, University of Colorado, Boulder, Colorado (April, 1976).

J. W. Gallagher, E. C. Beaty, and J. R. Rumble, "Bibliography of Low-Energy Electron and Photon Cross Section Data," Supplement (1975-1977) to NBS Special Publication 426 (to be published).

J. Berkowitz, Photoabsorption, Photoionization, and Photoelectron Spectroscopy (Academic, N.Y., 1979).

R. B. Cairns, H. Harrison, and R. I. Schoen, Advances in Atomic and Molecular Physics 8, 131 (Academic, N.Y., 1972).

C. R. Brundle and A. D. Baker (Eds.), Electron Spectroscopy: Theory, Techniques, and Applications 1 (Academic, N.Y., 1977).

General Comments

In this chapter data on both photoabsorption and photoionization is included. It should be mentioned that these are different things; photoionization is but one mechanism of photoabsorption. For atoms, however, at the low photon energies of relevance here ($h\nu < 100$ eV) the processes are virtually synonymous; mechanisms other than photoionization which contribute to the photoabsorption have negligibly small cross sections.

For molecules, however, the situation is not the same as for atoms. In addition to photoionization, photodissociation leaving two (or more) uncharged fragments is also a major contributor to photoabsorption. Thus, when molecular data are presented, a careful distinction is made: photoabosrption (the "total" process), photoionization (one mechanism, and this includes dissociative photoionization), and photodissociation (another mechanism) into neutral fragments.

Note Concerning Previous Volumes

In a previous set of two volumes (E. W. McDaniel, M. R. Flannery, H. W. Ellis, F. L. Eisele, W. Pope, and T. G. Roberts, Compilation of Data Relevant to Rare Gas - Rare Gas and Rare Gas - Monohalide Excimer Lasers, U.S. Army Missle Research and Development Command Technical Report H-78-1, December 1977) much of the photon collision data of interest here has been compiled. Rather than reproduce all of that data, it shall be referred to as "Previous Report" with specific volume and page numbers.

Generally, speaking, however, Vol. II, pp. 639-713, contains data on the nobles gases (ground and excited states), the halogen atoms, and Br_2 and I_2, relative (unnormalized) photoionization cross sections for the excimers Ar_2, Kr_2, Xe_2, KrAr, XeAr, XeKr, SeF_2, XeF_4, XeF_6, photodetachment of negative ions of atomic halogens, photodissociation of the molecular ions Ar_2^+, Kr_2^+, Xe_2^+, F_2^-, Cl_2^-, Br_2^-, and I_2^-, and free-free absorption of Ne, Ar, Kr, Xe, and Cl.

In this volume, the above data are referred to extensively and updated where necessary. In addition, data on a number of atoms and molecules species not treated in the previous volumes are presented.

D-1. PHOTOABSORPTION AND PHOTOIONIZATION CROSS SECTIONS OF ATOMS

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D-1.D.	Photoionization Cross Sections for Other Atoms (C, N, O, Cd, Hg)	1947
D-1.E.	Photoabsorption and Photoionization Cross Sections of Atoms: Data Needed	1965

Section D-1.A. PHOTOIONIZATION CROSS SECTION FOR ATOMIC HYDROGEN

The cross section for photoionization of atomic hydrogen are known virtually exactly [H. Hall, Rev. Mod. Phys. 8, 358 (1936)] both for the ground state as well as for any excited state. For the purposes of this compilation, data for 1s, 2s, 3s, 4s, 3p, and 3d initial states are presented. The data are calculated from the following formulas:

$$\sigma_{1s}(E) = 2^9 CE^{-4} A_1 B_1$$

$$\sigma_{2s}(E) = 2^6 C(E + 3/4)E^{-5} A_2 B_2$$

$$\sigma_{2p}(E) = 2^4 CE^{-5}[1 + 8(E + 3/4)E^{-1}]A_2 B_2/9$$

$$\sigma_{3s}(E) = 2^9 3^{-9} C(E + 8.9)\ (27E + 4)^2 E^{-7} A_3 B_3$$

$$\sigma_{3p}(E) = 2^{11} 3^{-10} C(81E^2 - 28E + 28/3)E^{-7} A_3 B_3$$

$$\sigma_{3d}(E) = 2^{12} 3^{-9} C(E + 8/9)\ (15E + 2)E^{-8} A_3 B_3/25$$

where E is the photon energy in Rybergs (= 13.6eV),

$$C = \pi^2 \alpha a_o^2/3,$$

$\alpha(\simeq 1/137)$ is the fine structure constant and A_o ($\simeq 5.28 \times 10^{-9}$cm) is the Bohr radius, and $A_n = [1 - \exp(-2\pi/k)]^{-1}$, $B_n = \exp[-\frac{4}{k}\tan^{-1}(nk)]$, $k = (E - 1/n^2)^{1/2}$. Using these expressions, the cross sections results on the following page have been tabulated.

Tabular D-1.A. Photoionization cross sections for the 1s, 2s, 2p, 3s, 3p, and 3d states of atomic hydrogen (units of cm^2).

HNU(EV)	LAMBDA(A)	1S	2S	2P	3S	3P	3D
1.5	8200.98	0.00E-01	0.00E-01	0.00E-01	2.52E-17	1.30E-17	1.08E-17
2.0	6074.80	0.00E-01	0.00E-01	0.00E-01	1.36E-17	6.13E-18	3.79E-18
2.7	4556.10	0.00E-01	0.00E-01	0.00E-01	7.36E-18	2.87E-18	1.33E-18
3.4	3644.88	0.00E-01	1.48E-17	4.06E-17	4.53E-18	1.55E-18	5.77E-19
4.1	3037.40	0.00E-01	1.00E-17	2.31E-17	3.02E-18	9.26E-19	2.86E-19
5.4	2278.05	0.00E-01	5.34E-18	9.29E-18	1.57E-18	3.97E-19	9.18E-20
6.8	1822.44	0.00E-01	3.21E-18	4.50E-18	9.34E-19	2.01E-19	3.71E-20
8.2	1518.70	0.00E-01	2.09E-18	2.46E-18	6.09E-19	1.13E-19	1.74E-20
9.5	1301.74	0.00E-01	1.45E-18	1.46E-18	4.16E-19	6.90E-20	9.07E-21
10.9	1139.03	0.00E-01	1.04E-18	9.26E-19	3.00E-19	4.46E-20	5.12E-21
12.2	1012.47	0.00E-01	7.79E-19	6.16E-19	2.24E-19	3.0[illegible]E-20	3.08E-21
13.6	911.22	6.30E-18	5.97E-19	4.27E-19	1.71E-19	2.12E-20	1.94E-21
15.0	828.38	4.88E-18	4.69E-19	3.05E-19	1.34E-19	1.53E-20	1.27E-21
16.3	759.35	3.86E-18	3.75E-19	2.24E-19	1.07E-19	1.14E-20	8.65E-22
17.7	700.94	3.10E-18	3.04E-19	1.68E-19	8.73E-20	8.61E-21	6.04E-22
19.0	650.87	2.53E-18	2.50E-19	1.29E-19	7.19E-20	6.65E-21	4.33E-22
20.4	607.48	2.09E-18	2.09E-19	1.01E-19	6.00E-20	5.21E-21	3.16E-22
21.8	569.51	1.75E-18	1.76E-19	7.95E-20	5.05E-20	4.15E-21	2.36E-22
23.1	536.01	1.47E-18	1.49E-19	6.37E-20	4.30E-20	3.34E-21	1.79E-22
24.5	506.23	1.25E-18	1.28E-19	5.16E-20	3.69E-20	2.72E-21	1.37E-22
25.8	479.59	1.08E-18	1.11E-19	4.23E-20	3.19E-20	2.24E-21	1.07E-22
27.2	455.61	9.31E-19	9.62E-20	3.[illegible]9E-20	2.77E-20	1.86E-21	8.44E-23
28.6	433.91	8.10E-19	8.42E-20	2.92E-20	2.43E-20	1.56E-21	6.72E-23
29.9	414.19	7.09E-19	7.41E-20	2.45E-20	2.14E-20	1.31E-21	5.41E-23
31.3	396.18	6.24E-19	6.59E-20	2.08E-20	1.89E-20	1.12E-21	4.39E-23
32.7	379.68	5.52E-19	5.82E-20	1.77E-20	1.68E-20	9.55E-22	3.60E-23
34.0	364.49	4.91E-19	5.20E-20	1.52E-20	1.50E-20	8.21E-22	2.97E-23
35.4	350.47	4.38E-19	4.66E-20	1.31E-20	1.35E-20	7.10E-22	2.47E-23
36.7	337.49	3.92E-19	4.19E-20	1.14E-20	1.21E-20	6.17E-22	2.06E-23
38.1	325.44	3.53E-19	3.78E-20	9.90E-21	1.09E-20	5.38E-22	1.74E-23
39.5	314.21	3.18E-19	3.43E-20	8.66E-21	9.91E-21	4.72E-22	1.47E-23
40.8	303.74	2.88E-19	3.11E-20	7.61E-21	9.01E-21	4.16E-22	1.25E-23
43.5	284.76	2.38E-19	2.59E-20	5.95E-21	7.51E-21	3.26E-22	9.19E-24
46.3	268.01	1.99E-19	2.18E-20	4.71E-21	6.32E-21	2.59E-22	6.87E-24
49.0	253.12	1.68E-19	1.85E-20	3.78E-21	5.36E-21	2.08E-22	5.22E-24
51.7	239.79	1.43E-19	1.58E-20	3.07E-21	4.59E-21	1.70E-22	4.02E-24
54.4	227.81	1.23E-19	1.36E-20	2.51E-21	3.96E-21	1.39E-22	3.13E-24
57.1	216.96	1.06E-19	1.18E-20	2.08E-21	3.44E-21	1.15E-22	2.47E-24
59.9	207.10	9.24E-20	1.03E-20	1.73E-21	3.00E-21	9.65E-23	1.97E-24
62.5	198.09	8.08E-20	9.07E-21	1.46E-21	2.64E-21	8.12E-23	1.59E-24
65.3	189.84	7.11E-20	8.00E-21	1.23E-21	2.33E-21	6.88E-23	1.29E-24
68.0	182.24	6.26E-20	7.10E-21	1.05E-21	2.07E-21	5.87E-23	1.09E-24
70.7	175.23	5.58E-20	6.32E-21	8.99E-22	1.84E-21	5.04E-23	8.70E-25
73.5	168.74	4.98E-20	5.65E-21	7.74E-22	1.65E-21	4.35E-23	7.22E-25
76.2	162.72	4.45E-20	5.07E-21	6.70E-22	1.48E-21	3.77E-23	6.04E-25
78.9	157.11	4.00E-20	4.57E-21	5.83E-22	1.33E-21	3.28E-23	5.08E-25
81.6	151.87	3.61E-20	4.13E-21	5.10E-22	1.21E-21	2.87E-23	4.29E-25
84.4	146.97	3.26E-20	3.74E-21	4.47E-22	1.09E-21	2.52E-23	3.65E-25
87.1	142.38	2.96E-20	3.40E-21	3.94E-22	9.94E-22	2.23E-23	3.12E-25
89.8	138.06	2.69E-20	3.10E-21	3.49E-22	9.06E-22	1.97E-23	2.67E-25
92.5	134.00	2.46E-20	2.84E-21	3.09E-22	8.29E-22	1.75E-23	2.30E-25
95.2	130.17	2.25E-20	2.60E-21	2.75E-22	7.59E-22	1.56E-23	1.99E-25

Reference: The above data were computed using the expressions on the previous page.

Section D-1.B. PHOTOIONIZATION CROSS SECTION FOR THE NOBLE GAS ATOMS

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D-1.B-7.	Photoionization cross section for the lowest 1/2s[1/2]0 excited states of Ne, Ar, Kr, and Xe	1933
D-1.B-8.	Photoionization cross section for the lowest 3/2s[3/2]2 excited states of Ne, Ar, Kr, and Xe	1934
D-1.B-9.	Photoionization cross section (theoretical) for the $2p^5 3s\ ^3P$ excited metastable state of Ne	1935

Photoionization Cross Sections for the Noble Gas Atoms: Ground States and Excited States

A. Ground States

Photoionization from the ground states of noble gas atoms has been treated rather completely in Vol. II, pp. 642-651.

B. Excited States

Experimental data on photoionization of excited metastable states of He (2^1S and 2^3S) and Ar, Kr, and Xe are given in Vol. II, pp. 660-661 and 663-666, respectively. In the following pages, later results are given for the excited metastable states of Ne, Ar, Kr, and Xe. These results supersede those of Vol. II since they are expected to be considerably more accurate.

Tabular Data D-1.B-1. Photoionization cross sections for excited 3s states of Ne (units of 10^{-19} cm^2).

Photoelectron Energy (Ryd)	State - $j_c \ell'[K]J$			
	$\frac{1}{2}s[\frac{1}{2}]1$	$\frac{3}{2}s[\frac{3}{2}]1$	$\frac{1}{2}s[\frac{1}{2}]0$	$\frac{3}{2}s[\frac{3}{2}]2$
0	0.93	3.87	0.98	1.62
0.04	0.61	4.17	0.31	0.58
0.10	0.58	2.53	0.21	0.14
0.15	0.94	3.09	0.42	0.11
0.30	1.49	2.89	1.22	0.46
0.50	2.12	1.35	2.89	1.10
0.70	2.15	0.76	5.13	1.92
0.90	2.21	0.97	6.52	2.24

Reference: These data were taken from T.W. Hardquist, J. Phys. B 11, 2101 (1978).

Note: The above data are theoretical, obtained using quantum defect theory. The estimated accuracy is ± 20%.

Comments: The notation designating the states: j_c is the angular momentum of the $2p^5$ core, ℓ' is the angular momentum of the excited electron, 3s in this case, K is the coupled angular momentum of j_c and ℓ', and J is the total angular momentum of the state.

Tabular Data D-1.B-2. Photoionization cross sections for excited 4s states of Ar (units of $10^{-19} cm^2$).

Photoelectron Energy (Ryd)	State - $j_c \ell'[K]J$			
	$\frac{1}{2}s[\frac{1}{2}]1$	$\frac{3}{2}s[\frac{3}{2}]1$	$\frac{1}{2}s[\frac{1}{2}]0$	$\frac{3}{2}s[\frac{3}{2}]2$
0	2.11	6.79	2.77	4.62
0.04	0.76	4.55	1.09	2.54
0.10	0.24	4.69	0.36	1.09
0.15	0.28	3.30	0.29	0.74
0.30	0.99	3.15	0.79	1.02
0.50	2.05	3.42	1.56	2.13
0.70	2.57	1.73	2.19	2.49
0.90	2.08	2.18	2.52	2.56

Reference: These data were taken from T.W. Hartquist, J. Phys. B <u>11</u>, 2101 (1978).

Note: The above data are theoretical, obtained using quantum defect theory. The estimated accuracy is ±20%.

Comments: The notation designating the states: j_c is the angular momentum of the $3p^5$ core, ℓ' is the angular mementum of the excited electron, 4s in this case, K is the coupled angular momentum of j_c and ℓ', and J is the total angular momentum of the state.

Tabular Data D-1.B-3. Photoionization cross sections for excited 5s states of Kr (units of 10^{-19} cm^2).

Photoelectron Energy (Ryd)	State - $j_c \ell'[K]J$			
	$\frac{1}{2}s[\frac{1}{2}]1$	$\frac{3}{2}s[\frac{3}{2}]1$	$\frac{1}{2}s[\frac{1}{2}]0$	$\frac{3}{2}s[\frac{3}{2}]2$
0	11.18	10.87	10.01	12.41
0.04	7.99	6.58	6.22	7.57
0.10	4.76	3.28	3.62	4.04
0.15	3.54	2.03	2.59	2.49
0.30	2.38	0.99	1.63	0.63
0.50	2.32	0.11	1.67	0.13
0.70	2.56	1.54	1.88	0.55
0.90	2.73	0.89	2.14	1.41

Reference: These data were taken from T.W. Hartquist, J. Phys. B 11, 2101 (1978).

Note: The above data are theoretical, obtained using quantum defect theory. The estimated accuracy is ±20%.

Comments: The notation designating the states: j_c is the angular momentum of the $4p^5$ core, ℓ' is the angular momentum of the excited electron, 5s in this case, K is the coupled angular momentum of j_c and ℓ', and J is the total angular momentum of the state.

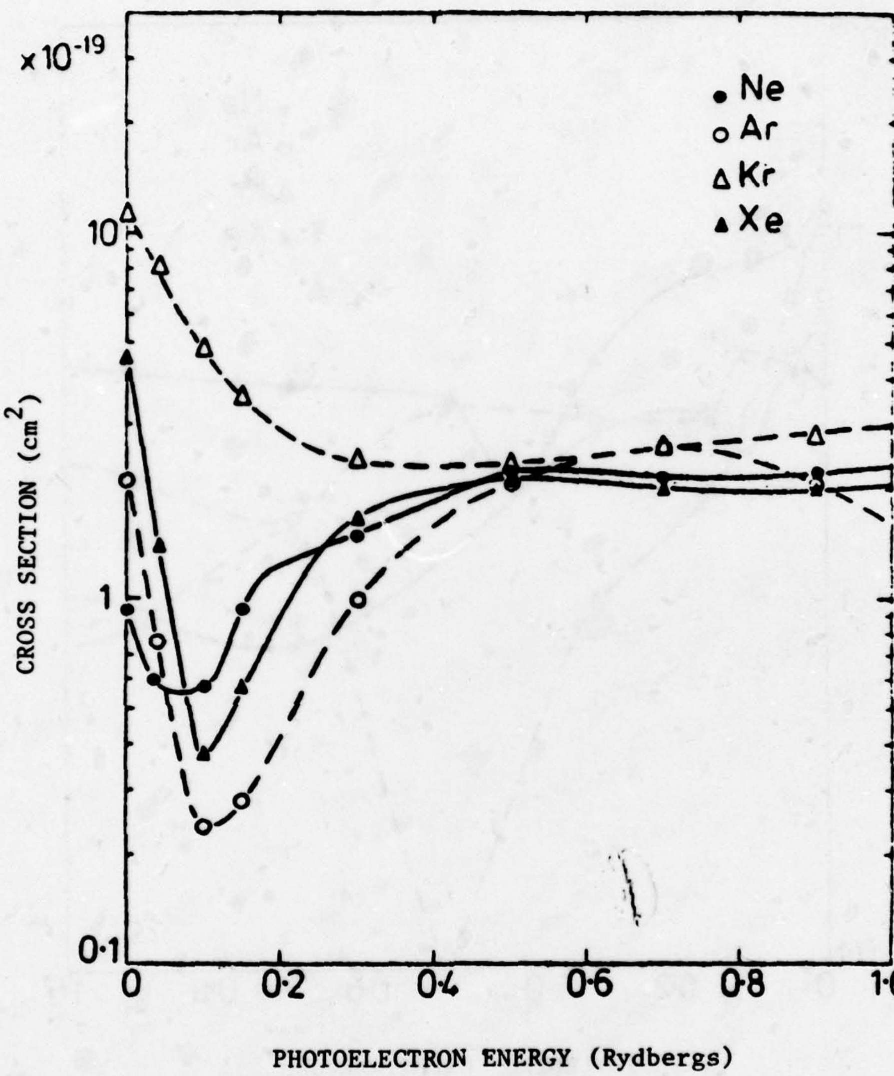
Tabular Data D-1.B-4. Photoionization cross sections for excited 6s states of Xe (units of 10^{-19} cm^2).

Photoelectron Energy (Ryd)	State - $j_c \ell'[K]J$			
	$\frac{1}{2}s[\frac{1}{2}]1$	$\frac{3}{2}s[\frac{3}{2}]1$	$\frac{1}{2}s[\frac{1}{2}]0$	$\frac{3}{2}s[\frac{3}{2}]2$
0	4.51	12.31	4.42	17.94
0.04	1.39	9.27	1.49	12.41
0.10	0.38	8.14	0.56	9.79
0.15	0.57	7.80	0.74	9.23
0.30	1.64	4.52	1.79	7.35
0.50	2.12	2.10	2.28	2.03
0.70	1.99	3.88	2.33	1.00
0.90	2.00	4.25	2.03	1.20

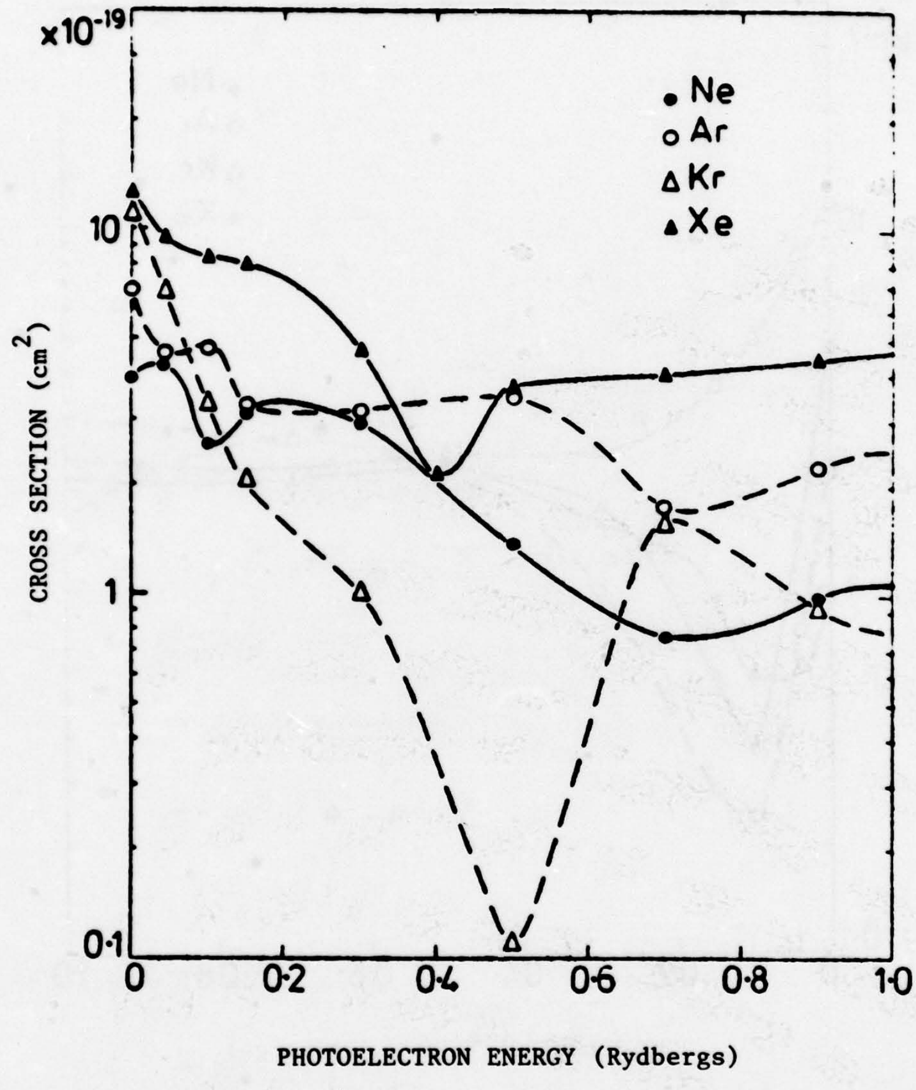
Reference: These data were taken from T.W. Hartquist, J. Phys. B 11, 2101 (1978).

Note: The above data are theoretical, obtained using quantum defect theory. The estimated accuracy is ±20%.

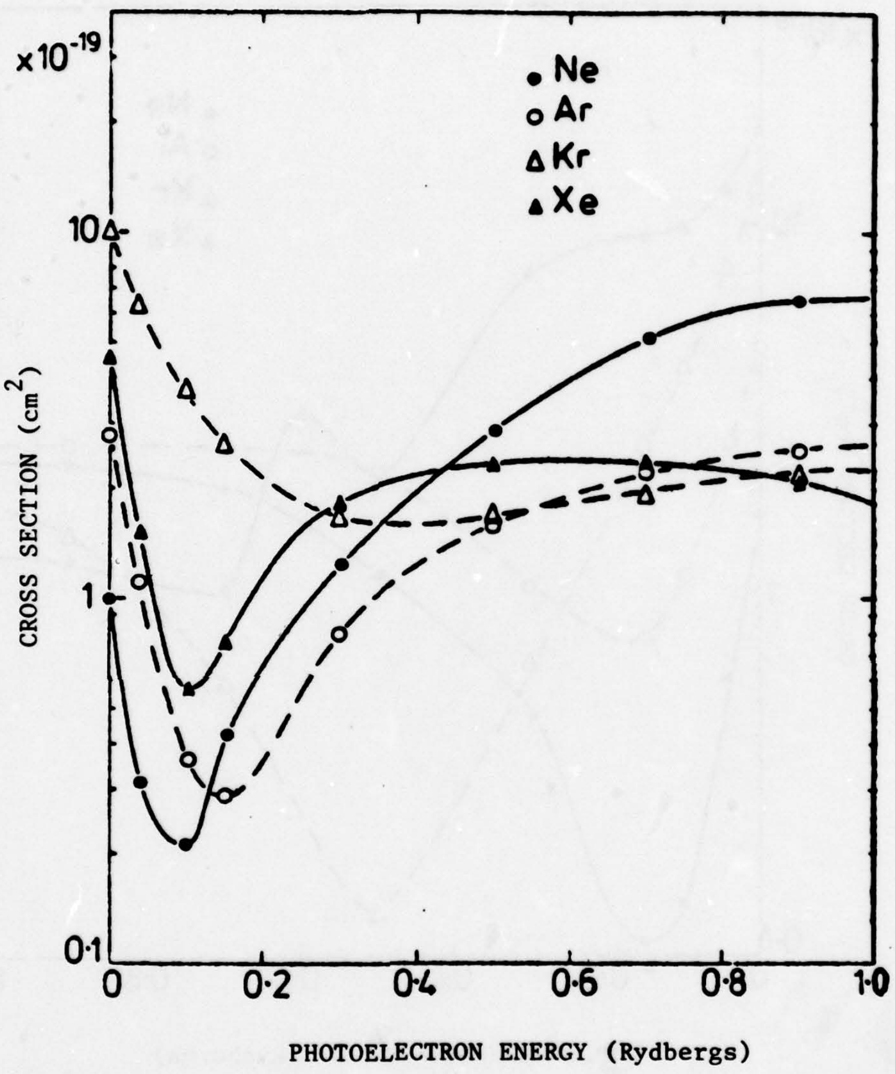
Comments: The notation designating the states: j_c is the angluar momentum of the $5p^5$ core, ℓ' is the angular mementum of the excited electron, 6s in this case, K is the coupled angular momentum of j_c and ℓ', and J is the total angular momentum of the state.



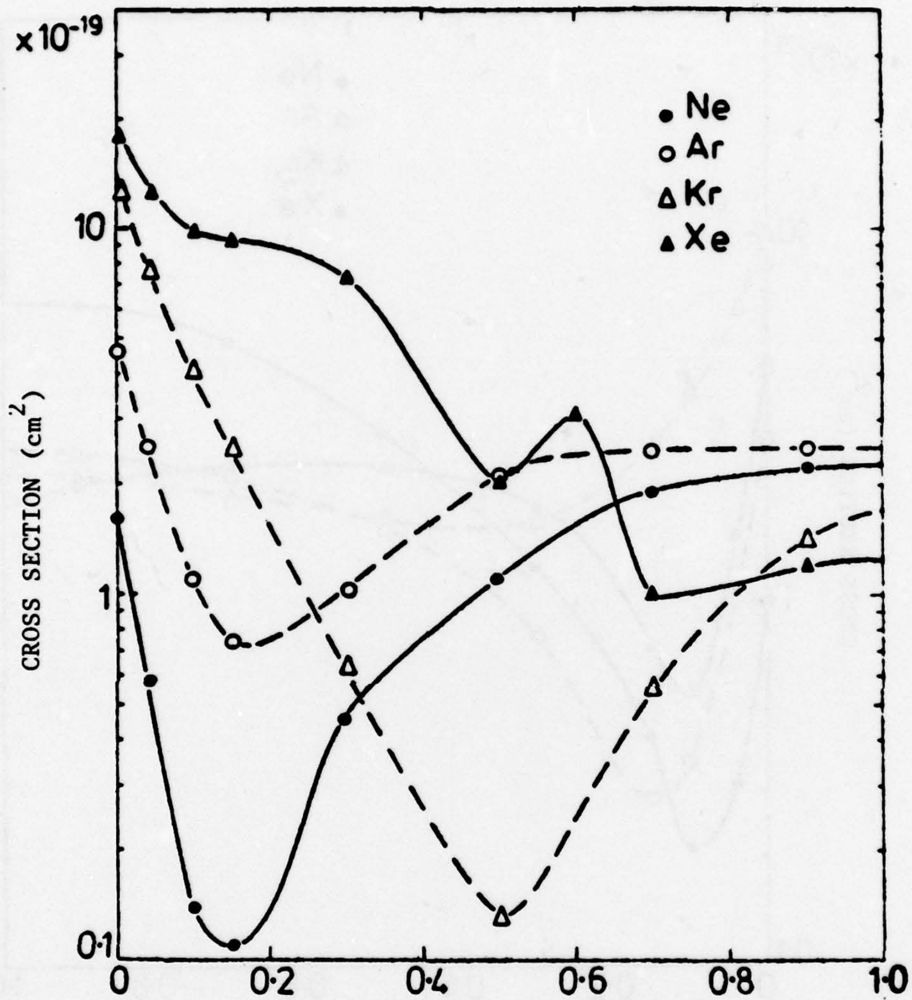
Graphical Data D-1.B-5. Photoionization cross section for the lowest 1/2s[1/2]1 excited states of Ne, Ar, Kr, and Xe taken from the data presented in D-1.B-1 through D-1.B-4.



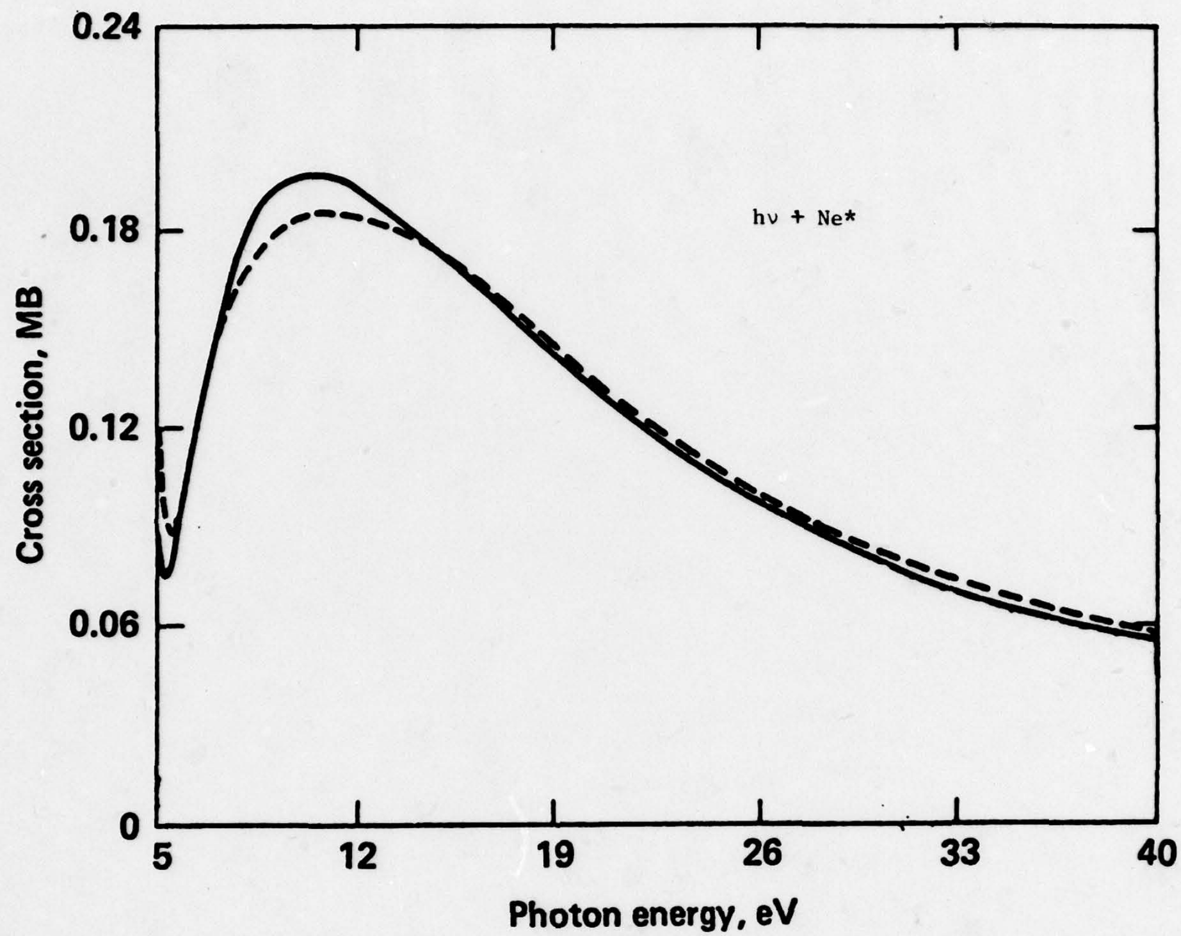
Graphical Data D-1.B-6. Photoionization cross section for the lowest 3/2s[3/2]1 excited states of Ne, Ar, Kr, and Xe taken from the data presented in D-1.B-1 through D-1.B-4.



Graphical Data D-1.B-7. Photoionization cross section for the lowest 1/2s[1/2]0 excited states of Ne, Ar, Kr, and Xe taken from the data presented in D-1.B-1 through D-1.B-4.



Graphical Data D-1.B-8. Photoionization cross section for the lowest 3/2s[3/2]2 excited states of Ne, Ar, Kr, and Xe taken from the data presented in D-1.B-1 through D-1.B-4.



Graphical Data D-1.B-9. Photoionization cross section (theoretical) for the $2p^5 3s\ ^3P$ excited metastable state of Ne. The solid and dashed curves are from velocity and length formulations, respectively. These data were taken from A.U. Hazi and T.N. Rescigno, Phys. Rev. A 16, 2376 (1977).

Section D-1.C. PHOTOIONIZATION CROSS SECTION FOR HALOGEN ATOMS (F, Cl, Br, I)

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Tabular Data D-1.C-1. Cross sections for the photoionization of atomic fluorine (units of Mb).

hν (Rydbergs)	^3P	^1D	^1S	Total
1.15	3.75	0	0	3.75
1.20	4.00	0	0	4.00
1.25	4.46	0	0	4.26
1.30	4.49	0	0	4.49
1.35	4.73	0	0	4.73
1.40	4.95	2.79	0	7.74
1.45	5.14	2.96	0	8.10
1.50	5.27	3.15	0	8.42
1.55	5.36	3.30	0	8.66
1.60	5.49	3.42	0	8.91
1.65	5.62	3.54	0	9.16
1.70	5.68	3.63	0.60	9.91
1.75	5.74	3.70	0.67	10.11
1.80	5.80	3.79	0.77	10.36
1.90	5.89	3.87	0.85	10.61
2.00	5.91	3.92	0.89	10.72
2.10	5.90	3.94	0.90	10.74
2.20	5.84	3.91	0.91	10.66
2.30	5.80	3.88	0.92	10.60
2.40	5.74	3.81	0.92	10.47
2.50	5.62	3.75	0.91	10.28
2.60	5.58	3.69	0.90	10.17
2.70	5.44	3.61	0.88	9.93
2.80	5.36	3.62	0.88	9.76
2.90	5.23	3.42	0.84	9.49
3.00	5.19	3.33	0.81	9.33
3.50	4.67	2.87	0.68	8.22
4.00	4.10	2.40	0.56	7.06
5.00	3.19	1.70	0.38	5.27
6.00	2.46	1.22	0.36	3.94
7.00	1.91	0.86	0.17	2.94

Note: The table gives the partial cross section to each of the states of the ground configuration of the positive ion. The total represents the sum or the total photoionization cross section. Note also that the calculated results include only the outer p-shell; the s-electrons, whose effects are small (~10%) are ignored.

Reference: The above data were taken from S.T. Manson, A.Z. Msezane, A.F. Starace and S. Shahabi, Phys. Rev. A (to be published).

Tabular Data D-1.C-2. Cross sections for the photoionization of atomic chlorine (units of Mb).

hν (Rydbergs)	^3P	^1D	^1S	Total
0.96	22.9	0	0	22.9
1.00	24.6	0	0	24.6
1.05	26.2	0	0	26.2
1.10	27.0	22.1	0	49.1
1.15	27.7	24.3	0	[illegible].0
1.20	28.1	24.5	0	52.6
1.25	28.1	24.0	6.42	58.5
1.30	28.0	22.5	6.38	56.9
1.40	26.4	18.9	5.59	50.9
1.50	24.6	14.4	4.15	43.2
1.60	22.5	11.0	3.09	36.6
1.70	19.9	8.52	2.16	31.6
1.80	17.2	6.30	1.49	25.0
1.90	14.7	4.29	1.10	20.0
2.00	12.1	3.17	0.77	16.04
2.10	10.0	2.27	0.51	12.78
2.20	8.10	1.69	0.37	10.16
2.30	6.50	1.29	0.27	8.06
2.40	5.11	0.99	0.20	6.30
2.50	4.08	0.72	0.15	4.95
2.60	3.16	0.55	0.12	3.83
2.70	2.46	0.43	0.094	2.98
2.80	1.94	0.35	0.078	2.37
2.90	1.46	0.29	0.066	1.82
3.00	1.11	0.24	0.057	1.41
3.50	0.35	0.18	0.045	1.58
4.00	0.26	0.20	0.045	0.51
5.00	0.28	0.24	0.052	0.57
6.00	0.47	0.26	0.054	0.78
7.00	0.48	0.23	0.050	0.76

Note: The table gives the partial cross section to each of the states of the ground configuration of the positive ion. The total represents the sum or the total photoionization cross section. Note also that the calculated results include only the outer p-shell; the s-electrons, whose effects are small (~10%) are ignored.

Reference: The above data were taken from S.T. Manson, A.Z. Msesane, A.F. Starace and S. Shahabi, Phys. Rev. A (to be published).

Tabular Data D-1.C-3. Cross sections for the photoionization of atomic bromine (units of Mb).

hν (Rydbergs)	^3P	^1D	^1S	Total
0.87	32.5	0	0	32.5
0.90	33.4	0	0	33.4
0.95	34.1	0	0	34.1
1.00	34.2	29.9	0	64.1
1.05	33.9	29.0	0	62.9
1.10	33.2	28.0	0	61.2
1.15	32.4	26.4	7.70	66.5
1.20	31.3	23.9	7.30	62.5
1.25	30.1	21.4	6.72	58.2
1.30	28.7	19.1	6.02	53.8
1.40	25.4	15.1	4.49	44.0
1.50	22.6	11.7	3.30	37.7
1.60	20.1	9.20	2.50	31.8
1.70	17.4	7.42	1.89	26.7
1.80	15.1	5.68	1.40	22.2
1.90	12.9	4.49	1.10	18.5
2.00	10.9	3.61	0.85	15.4
2.10	9.45	2.91	0.66	13.02
2.20	8.00	2.38	0.53	10.91
2.30	6.85	1.96	0.43	9.24
2.40	5.82	1.62	0.34	7.78
2.50	5.09	1.36	0.29	6.74
2.60	4.36	1.18	0.24	5.78
2.70	3.77	1.00	0.20	4.97
2.80	3.21	0.85	0.17	4.23
2.90	2.71	0.73	0.25	3.69
3.00	2.37	0.62	0.13	3.12
3.50	1.20	0.32	0.065	1.59
4.00	0.64	0.19	0.039	0.87
5.00	0.23	0.088	0.022	0.34
6.00	0.135	0.060	0.015	0.21
7.00	0.092	0.049	0.011	0.15

Note: The table gives the partial cross section to each of the states of the ground configuration of the positive ion. The total represents the sum or the total photoionization cross section. Note also that the calculated results include only the outer p-shell; the s-electrons, whose effects are small (~10%) are ignored.

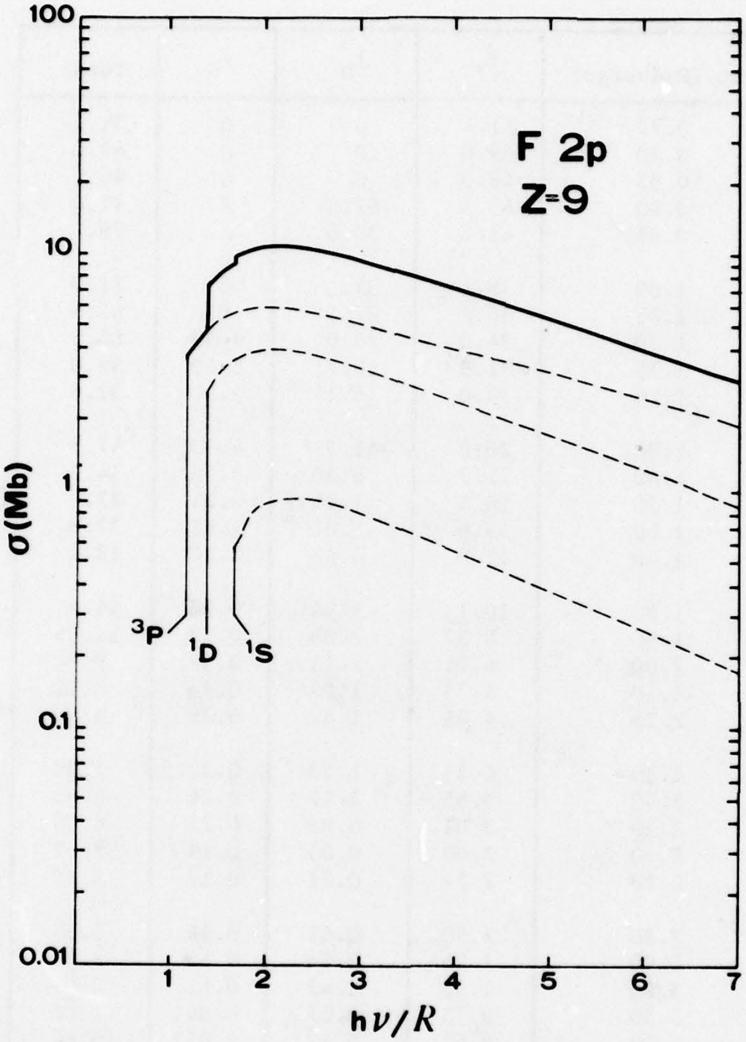
Reference: The above data were taken from S.T. Manson, A.Z. Msezane, A.F. Starace and S. Shahabi, Phys. Rev. A (to be published).

Tabular Data D-1.C-4. Cross sections for the photoionization of atomic iodine (units of Mb).

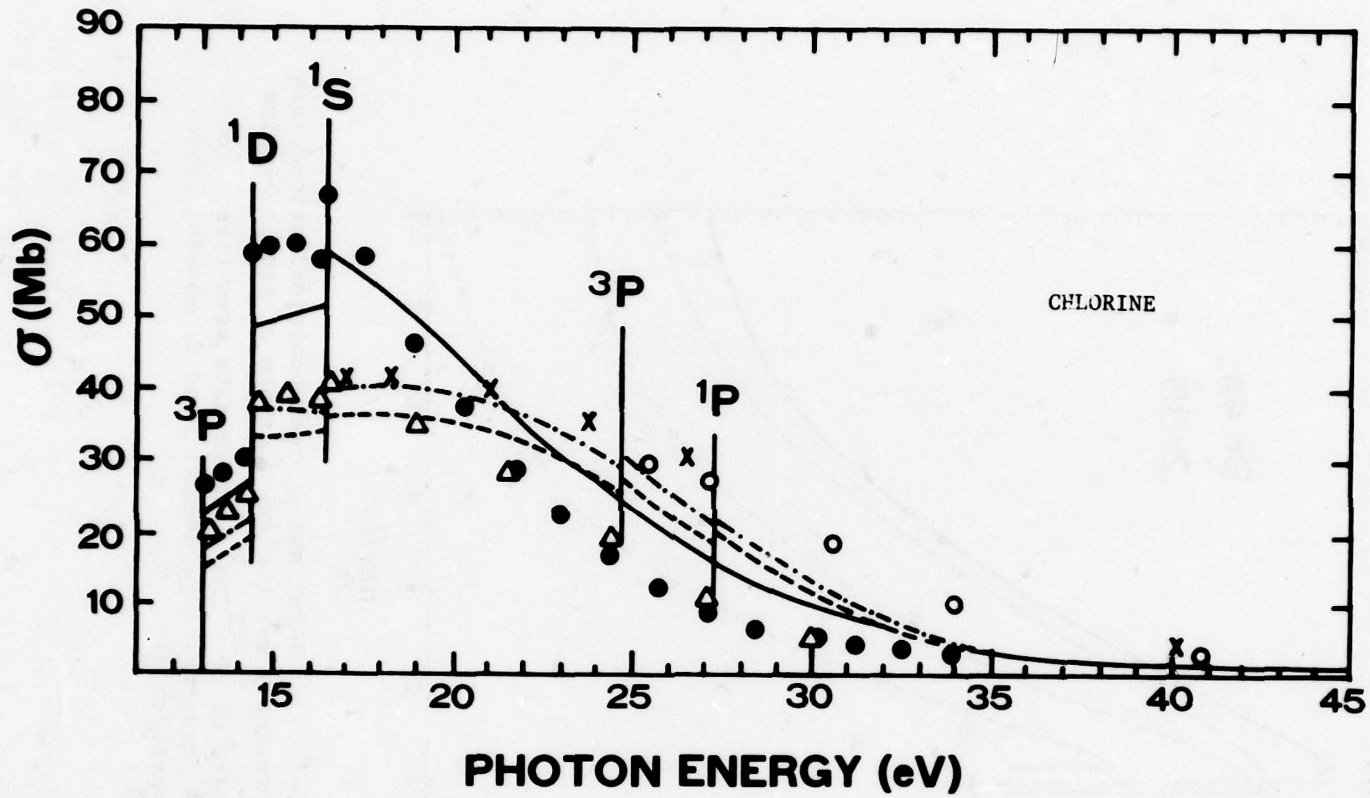
hν (Rydbergs)	^3P	^1D	^1S	Total
0.77	51.1	0	0	51.1
0.80	49.0	0	0	49.0
0.85	46.0	0	0	46.0
0.90	43.5	47.5	0	91.0
0.95	41.2	38.0	0	79.2
1.00	38.5	32.5	0	71.0
1.05	36.4	27.5	0	63.9
1.10	34.0	23.0	9.50	66.5
1.15	31.9	18.7	8.40	59.0
1.20	30.0	16.1	6.50	52.6
1.30	26.0	11.9	4.35	42.3
1.40	22.3	9.30	3.06	34.7
1.50	18.4	7.21	2.21	27.8
1.60	15.6	5.60	1.62	22.8
1.70	12.8	4.42	1.20	18.4
1.80	10.1	3.44	0.90	14.4
1.90	8.37	2.86	0.72	11.95
2.00	6.91	2.14	0.57	9.62
2.10	5.73	1.93	0.46	8.12
2.20	4.85	1.62	0.39	6.86
2.30	4.26	1.33	0.31	5.90
2.40	3.55	1.12	0.26	4.93
2.50	3.01	0.95	0.22	4.18
2.60	2.60	0.83	0.19	3.62
2.70	2.22	0.71	0.17	3.10
2.80	1.90	0.61	0.14	2.65
2.90	1.56	0.54	0.13	2.23
3.00	1.43	0.47	0.11	2.01
3.50	0.73	0.27	0.061	1.06
4.00	0.43	0.17	0.037	0.64
5.00	0.186	0.087	0.019	0.292
6.00	0.103	0.056	0.012	0.171
7.00	0.078	0.044	0.010	0.132

NOTE: The table gives the partial cross section to each of the states of the ground configuration of the positive ion. The total represents the sum or the total photoionization cross section. Note also that the calculated results include only the outer p-shell; the s-electrons, whose effects are small (~10%) are ignored.

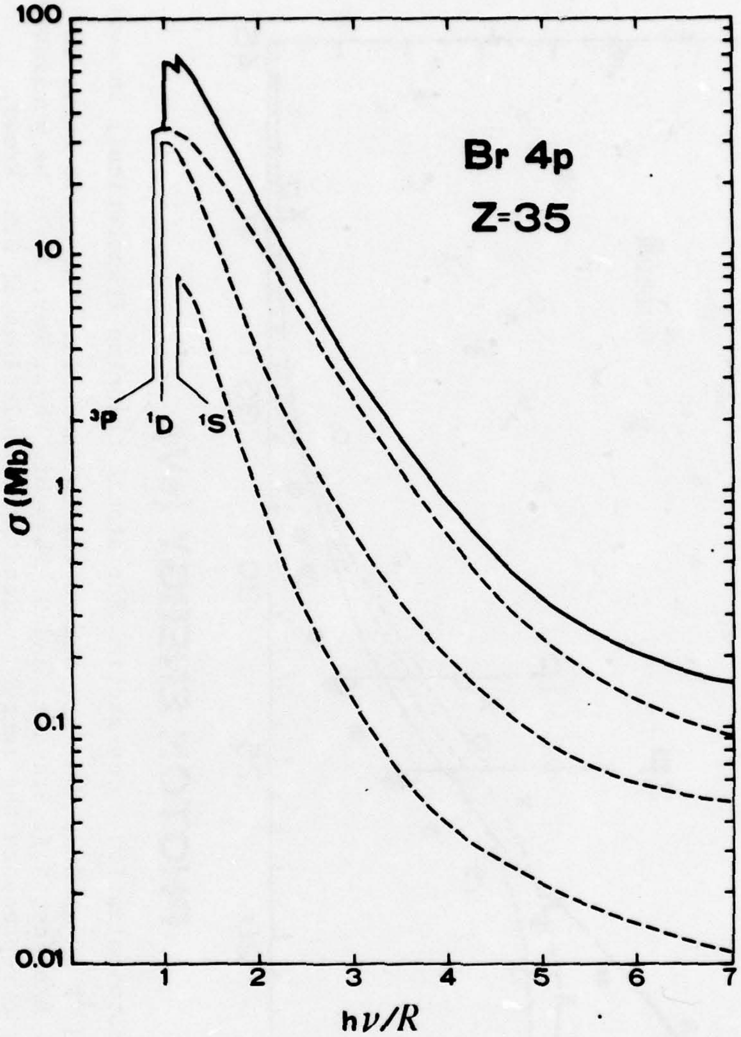
REFERENCE: The above data were taken from S.T. Manson, A.Z. Msezane, A.F. Starace and S. Shahabi, Phys. Rev. A (to be published).



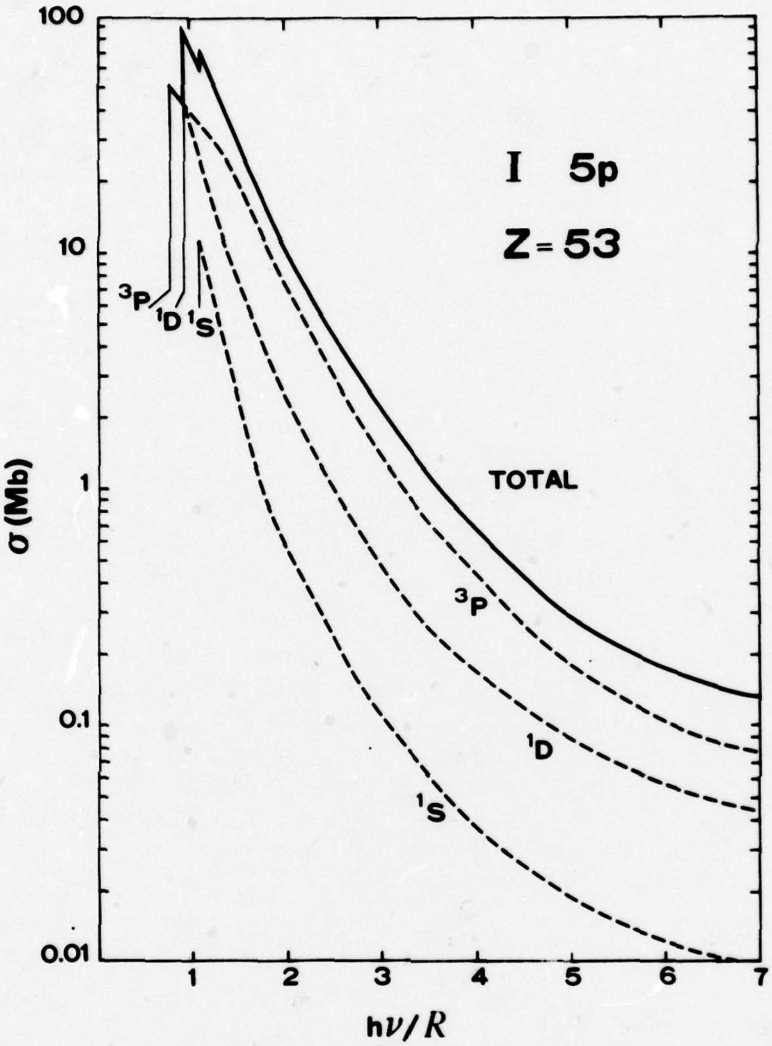
Graphical Data D-1.C-5. Total and partial photoionization cross sections (theoretical) for the ground state of atomic fluorine (2p only) in units of 10^{-18} cm^2. These data were taken from S.T. Manson, A. Msezane, A.F. Starace, and S. Shahabi, Phys. Rev. A (to be published).



Graphical Data D-1.C-6. Photoionization cross section for atomic chlorine (theoretical) in units of 10^{-18} cm^2. The ^3P and ^1P edges near 25 eV are due to the 3s subshell. The solid curve is the result of S.T. Manson, A. Msezane, A.F. Starace, and S. Shahabi, Phys. Rev. A (to be published), the dash-dot (dashed) curve represents the length (velocity) calculations of E.R. Brown, S.L. Carter, and H.P. Kelly, Phys. Rev. A 18, (1978), solid circles are from A.F. Starace and L. Armstrong, Jr., Phys. Rev. A 13, 1850 (1976), open circles M. Lamoureux and F. Combet Farnoux (to be published), crosses M.J. Coneely, Ph.D. Thesis, London University, 1969 (unpublished), and triangles N.A. Cherepkov and L.V. Chernysheva, Phys. Lett. 60A, 103 (1977).



Graphical Data D-1.C-7. Total and p[illegible]tial photoionization cross sections (theoretical) for the gr[illegible] state of atomic bromine 4p only) in units of 10^{-18} cm^2. These data were taken from S.T. Manson, A. Msezane, A.F. Starace, and S. Shahabi, Phys. Rev. A (to be published).



Graphical Data D-1.C-8. Total and partial photoionization cross sections (theoretical) for the ground state of atomic iodine (5p only) in units of 10^{-18} cm^2. These data were taken from S.T. Manson, A. Msezane, A.F. Starace, and S. Shahabi, Phys. Rev. A (to be published).

Section D-1.D. PHOTOIONIZATION CROSS SECTION FOR OTHER ATOMS (C, N, O, Cd, Hg)

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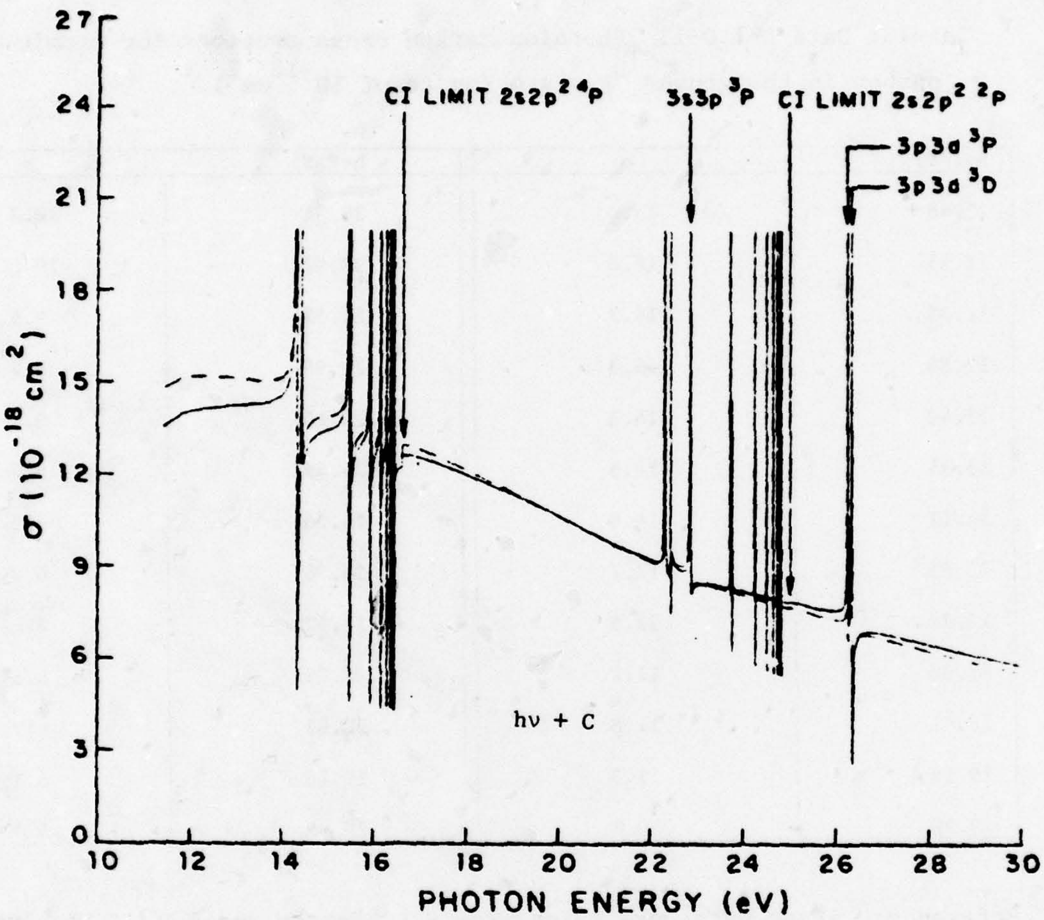
Tabular Data D-1.D-1. Photoionization cross sections for atomic carbon in the ground ^3P state (units of $10^{-18} cm^2$).

hν(eV)	σ	hν(eV)	σ
11.48	13.6	20.51	10.3
11.85	14.0	20.97	10.0
12.33	14.2	21.52	9.5
12.89	14.3	21.96	9.2
13.40	14.3	22.15	9.2
13.91	14.5	26.45	6.7
14.11	14.9	26.56	6.9
16.65	12.7	26.85	6.9
17.27	12.5	27.32	6.8
17.88	12.2	28.03	6.5
18.41	11.8	28.67	6.3
19.16	11.3	29.16	6.1
19.90	10.8	29.88	5.9

Reference: These data were taken from S.L. Carter and H.P. Kelly, Phys. Rev. A 13, 1388 (1976).

Note: The above are theoretical data in the length approximation using many-body-perturbation theory. The gaps around 15 eV and 23-25 eV are autoionizing regions. The details are given on the curve on the following page.

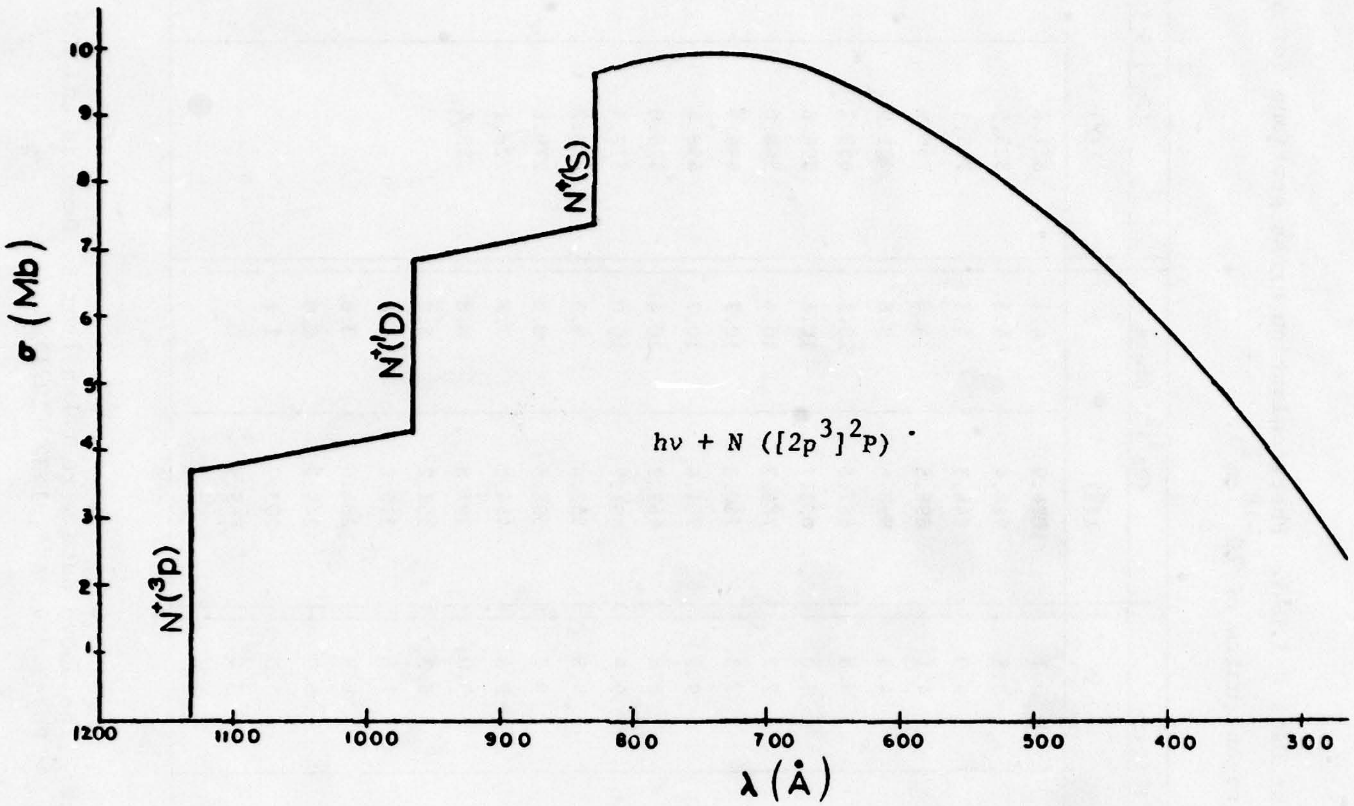


Graphical Data D-1.D-2. Photoionization cross section (theoretical) for ground ^3P state of atomic carbon calculated in length (solid) and velocity (dashed) formulations. All resonance peaks were truncated at 20 Mb. These data were taken from S.L. Carter and H.P. Kelly, Phys. Rev. A 13, 1388 (1976).

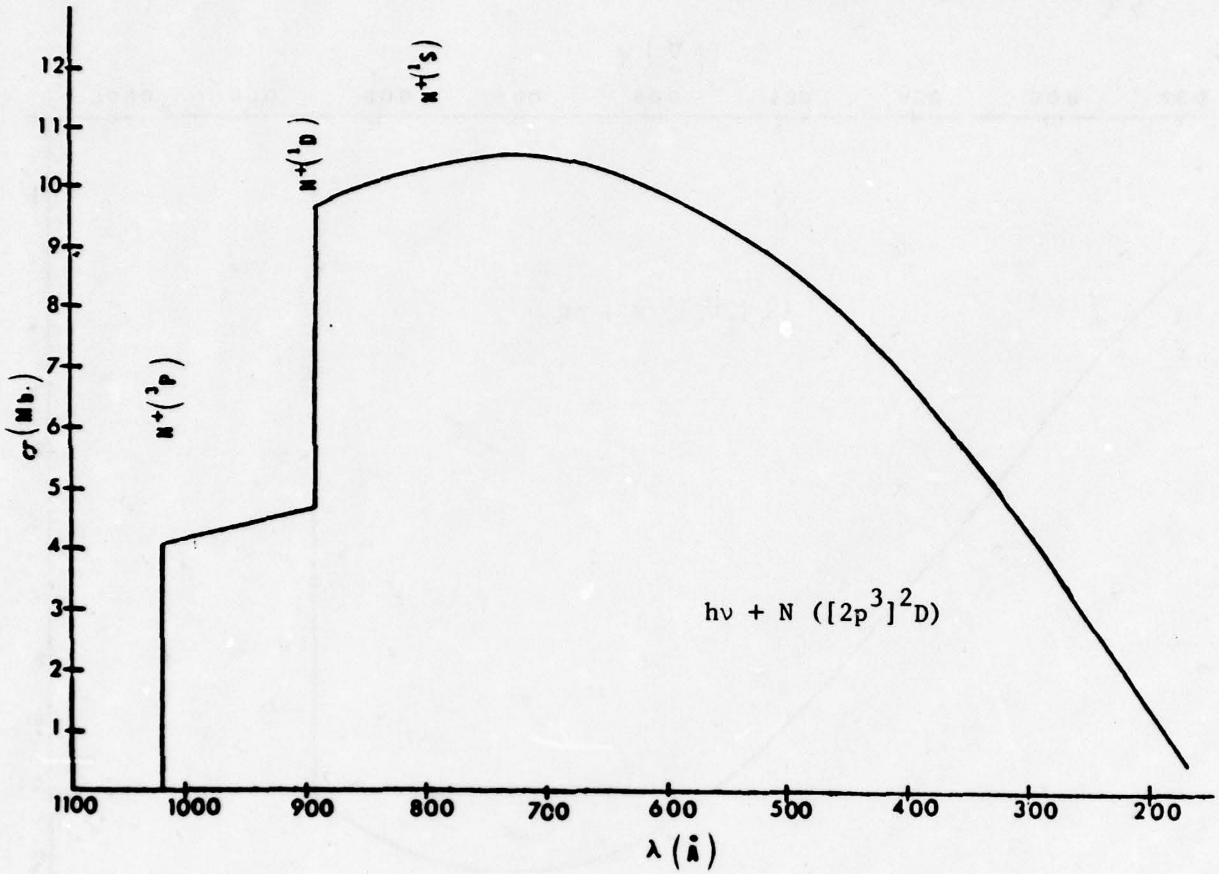
Tabular Data D-1.D-3. Photoionization cross sections for atomic nitrogen (units of $10^{-18} cm^2$).

$(2p^3)^2P$ State		$(2p^3)^2D$ State		$(2p^3)^4S$ State	
λ(Å)	σ	λ(Å)	σ	λ(Å)	σ
1133.2	3.7	1024.9	4.1	851.8	10.1
1102.8	3.8	988.4	4.3	825.5	10.5
1051.5	4.0	948.3	4.5	793.1	10.9
1020.7	4.1	898.5	4.8	756.9	11.1
967.8	4.3	898.6	9.8	711.9	11.3
967.4	6.8	867.5	10.1	653.7	11.2
925.4	7.0	833.7	10.4	596.8	10.7
876.6	7.2	788.3	10.6	540.0	9.9
831.2	7.3	750.3	10.7	496.9	9.1
831.0	9.5	701.4	10.7	458.4	8.2
791.8	9.8	647.2	10.4	426.0	7.5
764.2	9.9	601.7	10.0	377.9	6.4
723.7	9.8	552.4	9.5	328.2	5.2
683.2	9.7	506.5	8.8	279.6	4.0
639.4	9.4	444.2	7.8	226.1	2.8
602.4	9.0	397.8	6.8	185.4	2.0
547.3	8.3	357.2	5.8		
499.7	7.6	319.2	4.8		
457.8	6.9	281.4	3.8		
409.2	5.9	249.5	2.9		
365.1	5.0	203.7	1.6		
301.5	3.4	168.9	0.5		
239.5	1.6				

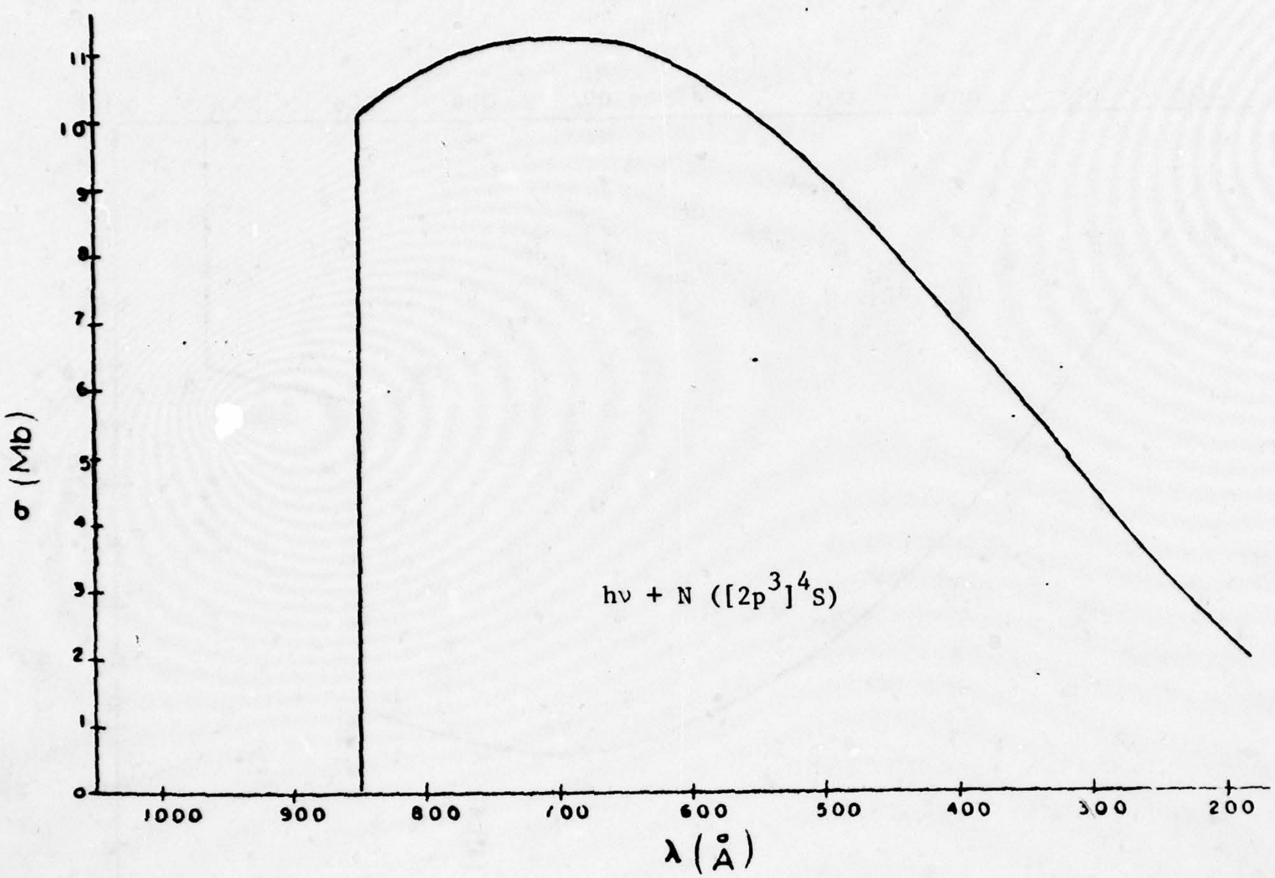
Reference: The above data were taken from S. Ormonde and M.J. Coneely, Phys. Rev. A 4, 1432 (1971).



Graphical Data D-1.D-4. Photoionization cross section (theoretical) for the $(2p^3)^2P$ ground state of atomic nitrogen. These data were taken from S. Ormonde and M.J. Coneely, Phys. Rev. A 4, 1432 (1971).



Graphical Data D-1.D-5. Photoionization cross section (theoretical) for the $(2p^3)^2D$ excited state of atomic nitrogen. These data were taken from S. Ormonde and M.J. Coneely, Phys. Rev. A 4, 1432 (1971).



Graphical Data D-1.D-6. Photoionization cross section (theoretical) for the $(2p^3)\,^4S$ excited state of atomic nitrogen. These 'ata were taken from S. Ormonde and M.J. Coneely, Phys. Rev. A 4, 1432 (1971).

Tabular Data D-1.D-7. Photoionization cross section for atomic oxygen in the ground (^3P) state (units of $10^{-18} cm^2$).

λ	σ	Ref.	λ	σ	Ref.
901.804	4.7	1	703.850		
901.108			702.899	13.0	1
			702.822		
895	4.5	2	702.332		
865	4.3	2	700.277	12.7	1
			699.408		
850.602	5.0	1			
			686.335		
840	5.0	2	685.816	17.3	1
			685.513		
834.462			684.996		
833.742	5.3	1			
833.326			683.278	11.8	1
832.927					
832.754			637.282	13.7	1
			636.818		
822.159	6.0	1			
			625.852		
780	4.9	2	625.130	13.0	1
			624.617		
779.905	11.1	1			
779.821			585.754	12.3	1
774.522	7.6	1	584.331	11.9	1
765	5.3	2	551.371	13.2	1
760.439	7.9	1	508.595	13.3	1
			508.434		
762.001					
761.130			500	11.9	3
760.445	8.3	1			
760.229			450	11.8	3
759.440					
758.677			400	11.1	3
743.70	7.6	1	350	9.8	3
735.89	14.3	1	300	8.6	3
725.542	16.7	1	250	6.7	3
715.645	12.2	1	200	4.4	3
715.599					
			150	2.3	3

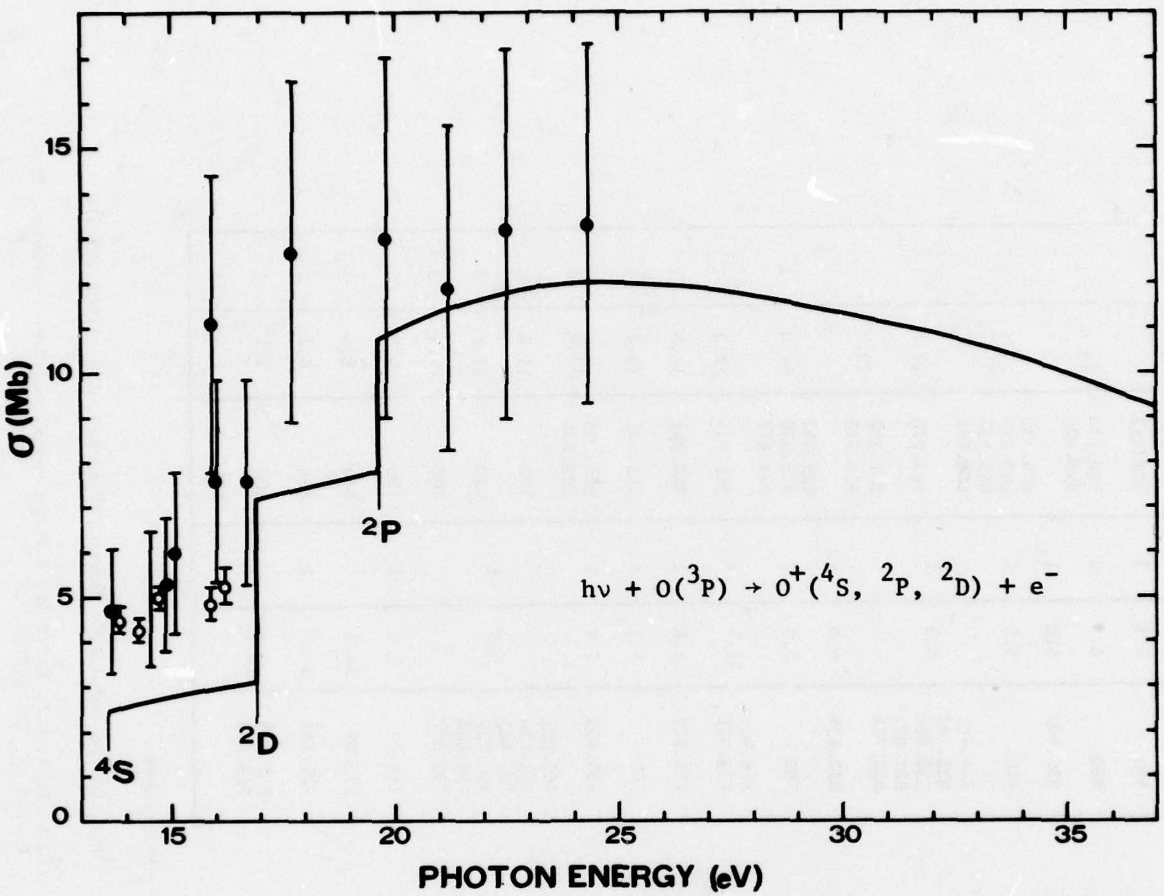
References:

[1] R.B. Cairns and J.A.R. Samson, Phys. Rev. 139, A1403 (1965).

[2] J.L. Kohl, G.P. Lafyatis, H.P. Palemius, and W.H. Parkinson, Phys. Rev. A 18, 571 (1978).

[3] A.F. Starace, S.T. Manson, and D.J. Kennedy, Phys. Rev. A 9, 2453 (1974).

Note: The accuracies of the data from References 1 and 2 (experimental) are ± 30% and ± 12%, respectively. The accuracy of the theoretical data from Reference 3 ($\lambda \leq 500$ Å) is ± 20%.



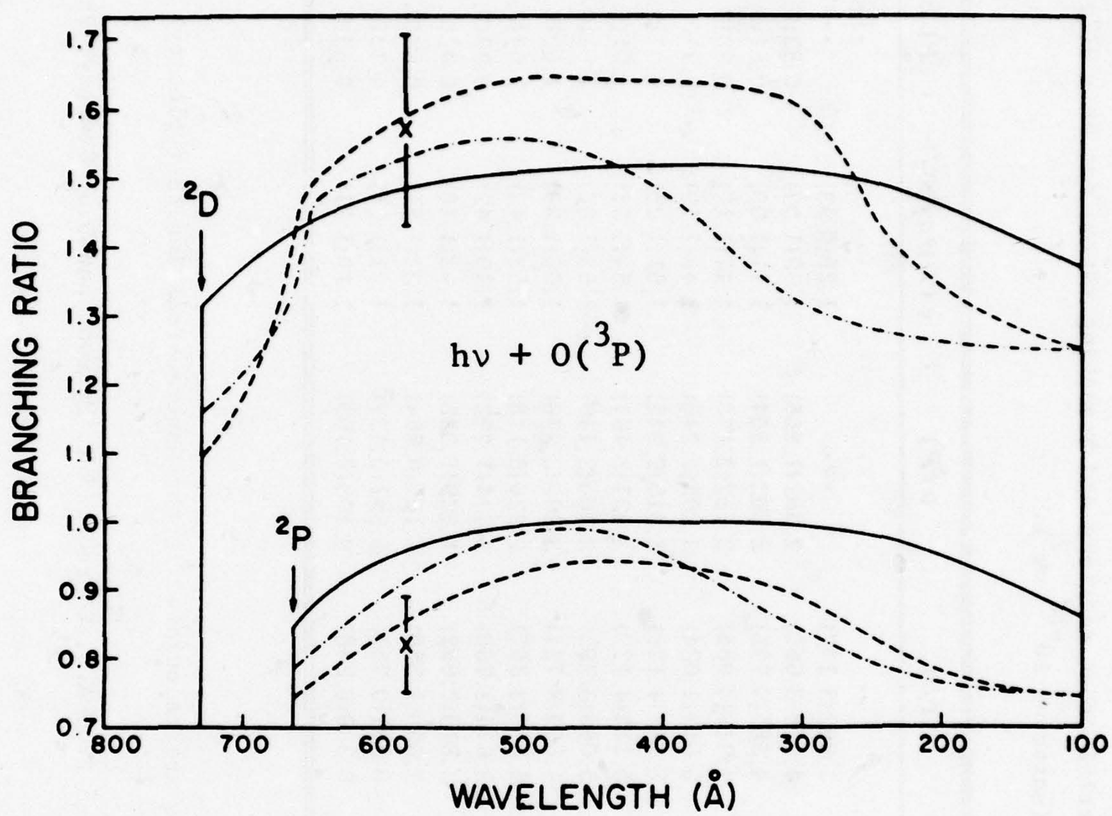
Graphical Data D-1.D-8. Total photoabsorption cross section for the ground (^3P) state of atomic oxygen. The experimental points are from R.B. Cairns and J.A.R. Samson, Phys. Rev. 139, A1403 (1965) (solid circles) and J.L. Kohl, G.P. Lafyatis, H.P. Palemius, and W.H. Parkinson, Phys. Rev. A 18, 571 (1978) (open circles). The solid curve is the theoretical result of A.F. Starace, S.T. Manson, and D.J. Kennedy, Phys. Rev. A 9, 2453 (1974).

Tabular Data D-1.D-9. Partial cross sections and branching ratios for $h\nu + O(2p^4\ {}^3P) \rightarrow O^+(2p^3\ {}^4S,\ {}^2D,\ {}^2P) + e$ (units of $10^{-18}\ cm^2$).

λ(Å)	$\sigma(^4S)$	$\sigma(^2D)$	$\sigma(^2P)$	$\sigma(^2D)/\sigma(^4S)$	$\sigma(^2P)/\sigma(^4S)$
909.8	2.463(2.892)	...	...	...	...
731.4	3.122(3.399)	3.982(3.177)	...	1.28(0.93)	...
665.0	3.285(3.450)	4.578(3.685)	2.682(1.806)	1.39(1.07)	0.82(0.52)
650.0	3.321(3.461)	4.685(3.775)	2.802(1.904)	1.41(1.09)	0.84(0.55)
600.0	3.374(3.400)	4.948(3.985)	3.122(2.173)	1.47(1.17)	0.93(0.64)
581.3	3.391(3.381)	5.013(4.034)	3.205(2.246)	1.48(1.19)	0.95(0.66)
550.0	3.400(3.308)	5.142(4.129)	3.315(2.348)	1.51(1.25)	0.97(0.71)
500.0	3.374(3.159)	5.183(4.122)	3.421(2.451)	1.54(1.31)	1.01(0.78)
450.0	3.275(2.943)	5.085(3.992)	3.400(2.449)	1.55(1.36)	1.04(0.83)
400.0	3.097(2.668)	4.809(3.721)	3.239(2.338)	1.55(1.39)	1.05(0.88)
350.0	2.827(2.332)	4.336(3.307)	2.926(2.116)	1.53(1.42)	1.04(0.91)
300.0	2.461(1.940)	3.674(2.760)	2.444(1.772)	1.49(1.42)	0.99(0.91)
250.0	1.979(1.496)	2.813(2.092)	1.829(1.335)	1.42(1.40)	0.92(0.89)
200.0	1.405(1.028)	1.850(1.380)	1.157(0.864)	1.32(1.34)	0.82(0.84)
150.0	0.815(0.588)	0.991(0.751)	0.591(0.457)	1.21(1.28)	0.72(0.78)
100.0	0.308(0.222)	0.339(0.268)	0.193(0.159)	1.10(1.21)	0.63(0.72)

Note: These theoretical results are calculated in the Hartree-Fock length (velocity) formulation.

Reference: These data were taken from A.F. Starace, S.T. Manson, and D.J. Kennedy, Phys. Rev. A 9, 2453 (1974).



Graphical Data D-1.D-10. Branching ratios $\sigma(^2D)/\sigma(^4S)$ and $\sigma(^2P)/\sigma(^4S)$ for photoionization of the ground state of atomic oxygen. The dot-dashed (dashed) curves are the theoretical length (velocity) results of R.J.W. Henry, Plant. Space Sci. 15, 1747 (1967); the solid lines are the results of A.F. Starace, S.T. Manson and D.J. Kennedy, Phys. Rev. A 9, 2453 (1974); and the crosses are experimental points of J.A.R. Samson and V.E. Petrosky, Phys. Rev. A 9, 2449 (1974).

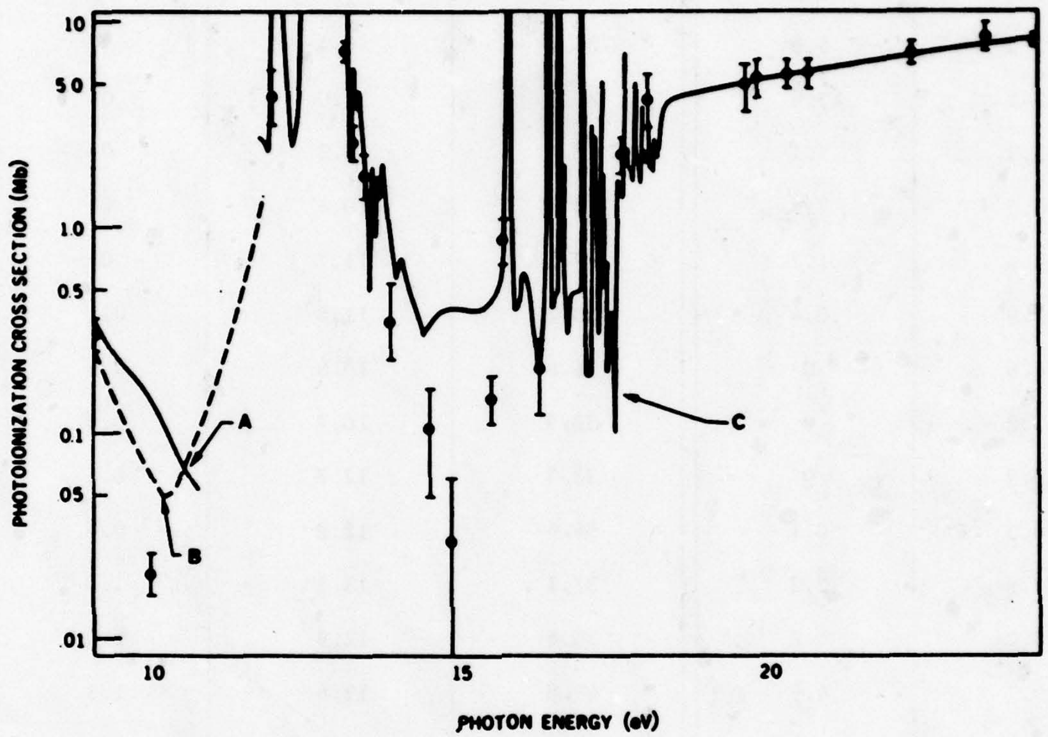
Tabular Data D-1.D-11. Photoionization cross section for atomic Cd (units of $10^{-18} cm^2$).

$h\nu$(eV)	$\sigma(Cd^+)$	$h\nu$(eV)	$\sigma(Cd^+)$	$\sigma(Cd^{++})$
9.1	0.2	25.9	8.8	0
12.0	4.5	26.5	9.4	0
12.1	13.9	27.3	9.0	0
13.3	7.1	27.4	10.2	0
13.5	2.6	28.6	10.4	0
13.6	1.7	29.5	11.7	0
13.9	0.4	30.2	11.6	0.1
14.6	0	31.6	10.8	0.4
15.2	0	32.9	10.7	0.6
15.9	0	33.3	12.7	0.6
16.3	0.1	34.6	12.3	0.6
17.6	2.2	37.1	13.8	1.0
18.2	4.2	38.6	12.9	1.0
19.7	4.9	43.8	13.6	1.3
20.1	5.3	45.5	14.5	1.3
20.5	5.7	50.2	12.9	1.7
20.9	5.6	52.2	13.2	1.9
22.4	7.1	64.1	10.9	3.2
23.7	8.8	71.5	9.4	3.4
24.6	8.1	82.6	7.6	4.9
25.2	9.1			

Reference: These data were taken from R.B. Cairns, H. Harrsion, and R.I. Schoen, J. Chem. Phys. 53, 96 (1970).

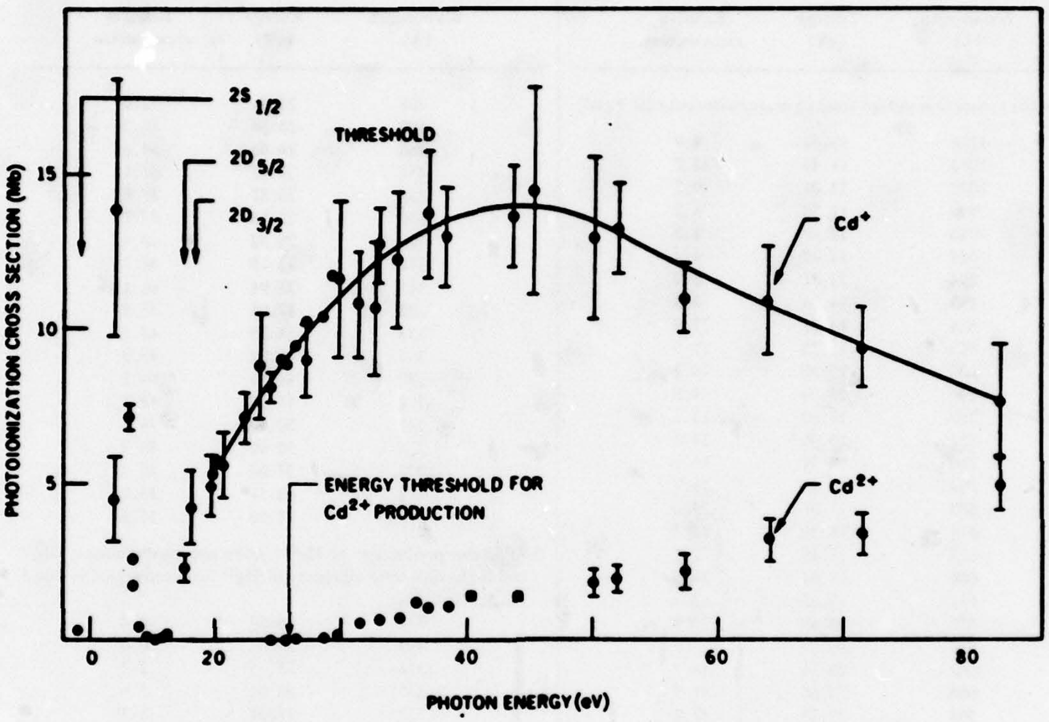
Note: The accuracy of these data is ±25%.

hν + Cd



Graphical Data D-1.D-12. Photoionization cross section of atomic Cd in the threshold region. These data were taken from R.B. Cairns, H. Harrison, and R.I. Schoen, Advances in Atomic and Molecular Physics 8, 131 (1972). The original data are from: (●) R.B. Cairns, H. Harrison, and R.I. Schoen, J. Chem. Phys. 53, 96 (1970); Curve A, K.J. Ross and G.V. Marr, Proc. Phys. Soc. 85, 193 (1965); Curve B, J. Berkowitz and C.J. Lifshitz, J. Phys. B 1, 438 (1968); and Curve C, G.V. Marr and J.M. Austin, Proc. Roy. Soc. A 310, 137 (1969).

$h\nu$ + Cd

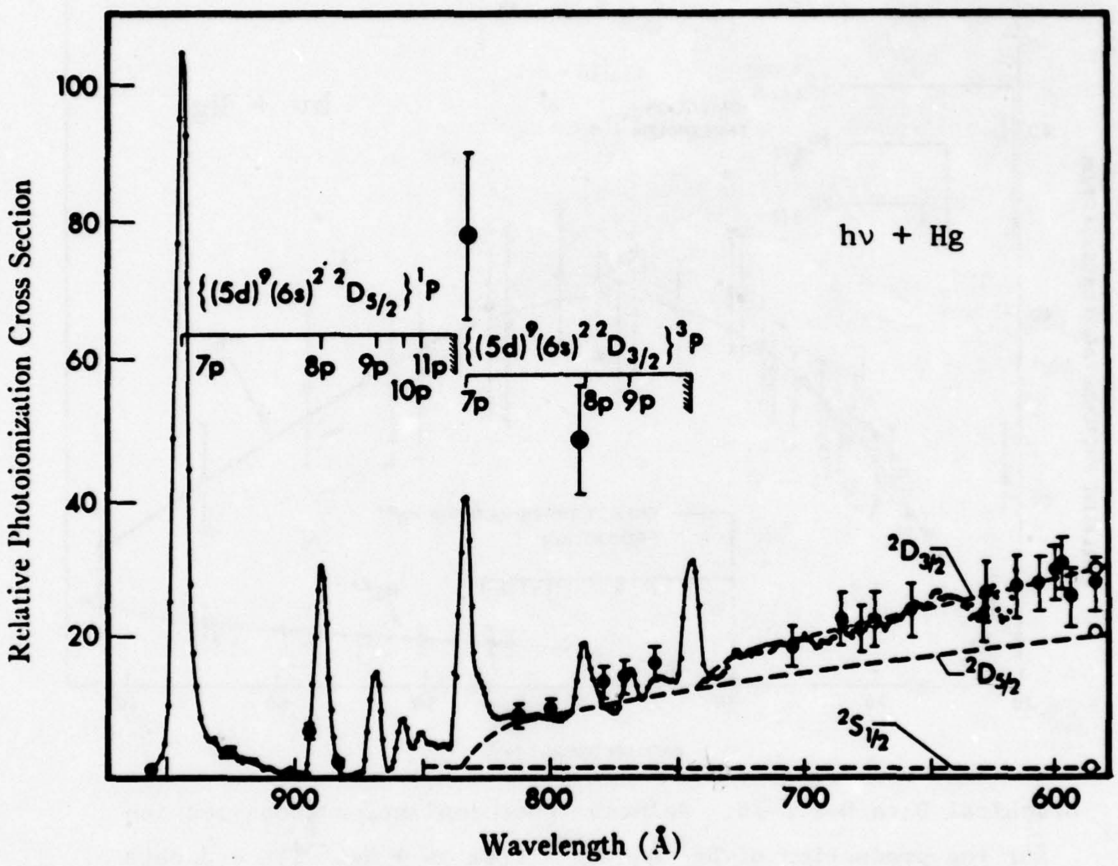


Graphical Data D-1.D-13. Photoionization cross sections of atomic Cd to produce Cd^+ and Cd^{++}. These data were taken from R.B. Cairns, H. Harrison, and R.I. Schoen, J. Chem. Phys. 53, 96 (1970).

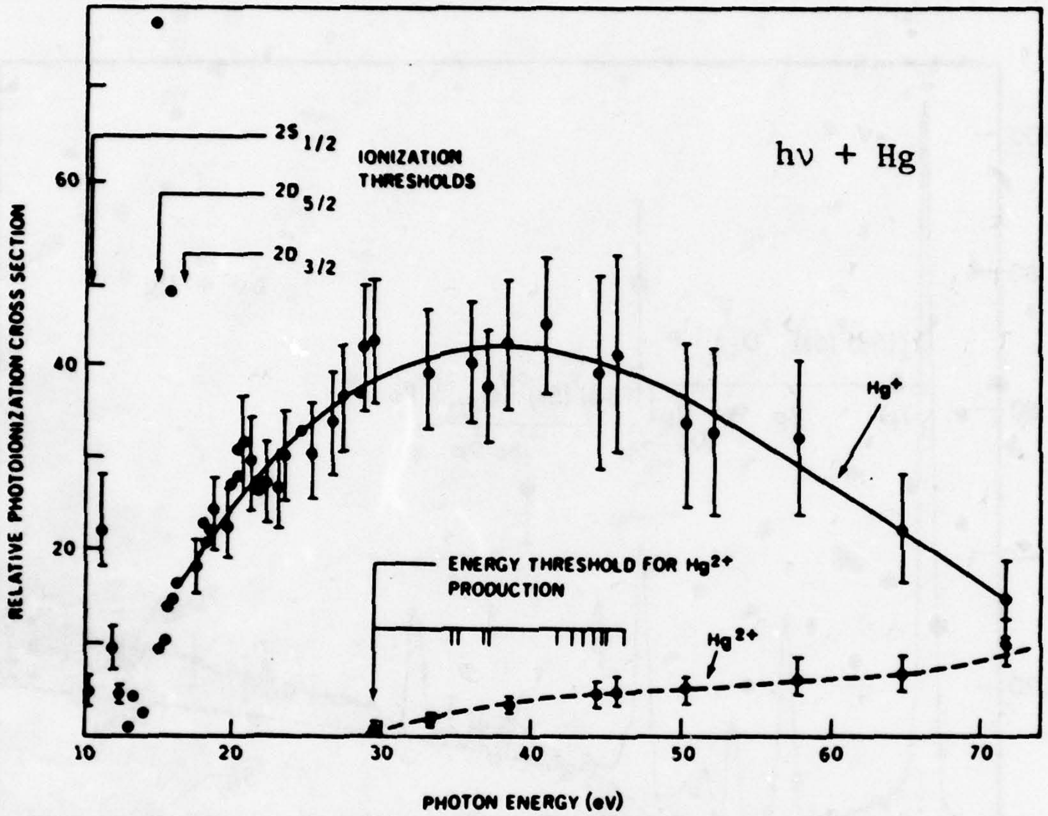
Tabular Data D-1.D-14. Photoionization cross section for Hg.

Wavelength (Å)	Energy (eV)	Relative cross section
A. For the production of Hg^+ (units are approximately 10^{-18} cm^2)		
1176	10.54	4.9
1084	11.44	22.7
1032	12.01	9.5
990	12.52	4.2
955	12.98	1.3
924	13.42	4.2
894	13.87	6.9
883	14.04	2.3
834	14.87	77.9
813	15.25	9.5
800	15.50	10.2
790	15.69	48.6
780	15.89	14.1
772	16.06	14.8
760	16.31	16.7
703	17.64	18.7
686	18.07	23.0
678	18.29	21.7
672	18.45	22.7
658	18.84	24.6
631	19.65	23.3
630	19.68	26.9
617	20.09	27.9
608	20.36	28.2
600	20.66	31.5
598	20.73	32.2
596	20.80	26.9
583	21.27	30.2
572	21.67	28.2
569	21.79	26.9
555	22.34	27.9
536	23.13	27.3
525	23.61	30.9
508	24.41	32.9
490	25.30	31.2
465	26.66	34.5
452	27.43	37.1
434	28.57	37.8
430	28.83	42.7
420	29.52	43.4
374	33.15	40.1
345	35.94	41.1
335	37.01	38.4
323	38.38	43.1
303	40.92	45.0
280	44.28	40.1
272	45.58	42.1
247	50.19	34.2
238	52.09	33.5
215	57.66	32.9
192	64.57	23.0
172	71.66	15.4
B. For the production of Hg^{2+} (units are approximately 10^{-18} cm^2 if the detection efficiency of Hg^{2+} ions is assumed to equal that of Hg^+ ions)		
434	28.57	0.2
419	29.52	0.8
374	33.15	2.2
345	35.94	3.6
335	37.01	3.4
323	38.38	3.6
283	44.28	4.5
272	45.58	5.2
247	50.19	5.0
215	57.66	6.5
192	64.57	6.9
173	71.66	10.9

Reference: These data were taken from R.B. Cairns, H. Harrison, and R.I. Schoen, J. Chem. Phys. 53, 96 (1970).



Graphical Data D-1.D-15. Relative photoionization cross section for the production of Hg^{+} from hν + Hg. The ordinate units are approximately equal to 10^{-18} cm^{2}. These data were taken form R. B. Cairns, H. Harrison, and R. I. Schoen, J. Chem. Phys. 53, 96 (1970).



Graphical Data D-1.D-16. Relative photoionization cross section for the production of Hg^+ and Hg^{++} from hν + Hg. The ordinate units are approximately equal to $10^{-18} cm^2$. These data were taken from R. B. Cairns, H. Harrison, and R. I. Schoen, J. Chem. Phys. 53, 96 (1970).

Section D-1.E. PHOTOABSORPTION AND PHOTOIONIZATION CROSS SECTIONS OF ATOMS: DATA NEEDED

I. Ground States:

A) Halogen Atoms - Only theoretical data exist for the halogens F, Cl, Br, and I. Experimental data, though difficult to obtain, would be highly desirable as none now is extant. This is particularly important in the threshold region where the calculations are the least accurate, for example from the threshold to $h\nu \sim 30$ eV.

B) Other Atoms - For atomic U there are no data in the energy region of interest, threshold to $h\nu \sim 50$ eV. These data are very high priority items. In addition, the data for atomic C and N is almost entirely theoretical; the only experimental work to date is somewhat suspect. Thus good experimental data for C and N are both important in the threshold to 50 eV region. The data for Hg need to be made absolute.

II. Excited States:

A) Noble Gases - Experimental data exist only for the He 2^1S and 2^3S metastable states. Resonably reliable theoretical data exist for the lowest metastable $np^5(n+1)s$ states of Ne, Ar, Kr, and Xe. Experimental data are needed for these cases as well as for other excited states which are metastable or just reasonably long-lived.

B) Halogen and Other Atoms - Except for some theoretical photoionization cross sections for excited multiples of the ground configuration of atomic C and O, no data exist. Data are urgently needed for all metastable and other long-lived excited states of atomic C, N, O, Cd, Hg, and (especially) U.

D-2. PHOTOABSORPTION, PHOTOIONIZATION, AND PHOTODISSOCIATION CROSS SECTIONS OF MOLECULES (MONOMERS)

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D-2.A.	Photoabsorption Cross Sections for Br_2 and I_2	1968
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D-2.C.	Photoabsorption Cross Sections for CH_4, CO, CO_2, ClO, O_3, HCl, H_2O, D_2O, $HgBr_2$, HgI_2, ICN, NH_3, N_2O, NO, NO_2, and UF_6	1987
D-2.D.	Relative Photoabsorption, Photoionization, and Photodissociation Cross Sections for BrCN, CH_3Br, CH_3Cl, CH_3F, C_2N_2, ClCN, ClF, F_2, FCN, F_2O, HCl, HF, ICN, and NO_2	2011
D-2.E.	Photoabsorption Cross Sections (Extinction Coefficients) for Cl_2, Br_2, BrCl, ICl, IBr, HI, and HBr	2031
D-2.F.	Photoabsorption, Photoionization, and Photodissociation Cross Sections of Molecules (Monomers): Data Needed . . .	2034

Section D-2.A. PHOTOABSORPTION CROSS SECTIONS FOR Br_2 AND I_2

Experimental results for the absolute photoabsorption cross section for Br_2 and I_2 from threshold to $\lambda = 600$ Å ($h\nu \approx 20$ eV) are given in Vol. II, pp. 652-655. These results have not been superceded.

Section D-2.B. PHOTOABSORPTION CROSS SECTIONS FOR H_2, D_2, N_2, AND O_2

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D-2.B-1.	Photoabsorption Cross Sections for H_2 and D_2	1970
D-2.B-2.	Photoabsorption Cross Section for H_2	1971
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D-2.B-4.	Photoabsorption Cross Section for D_2	1973
D-2.B-5.	Photoabsorption Cross Section for D_2	1974
D-2.B-6.	Photoabsorption Cross Sections for N_2	1975
D-2.B-7.	Photoabsorption Cross Section of N_2	1976
D-2.B-8.	Photoabsorption Cross Section for N_2	1977
D-2.B-9.	Photoabsorption Cross Sections for O_2	1978
D-2.B-10.	Photoabsorption Cross Section of O_2	1984
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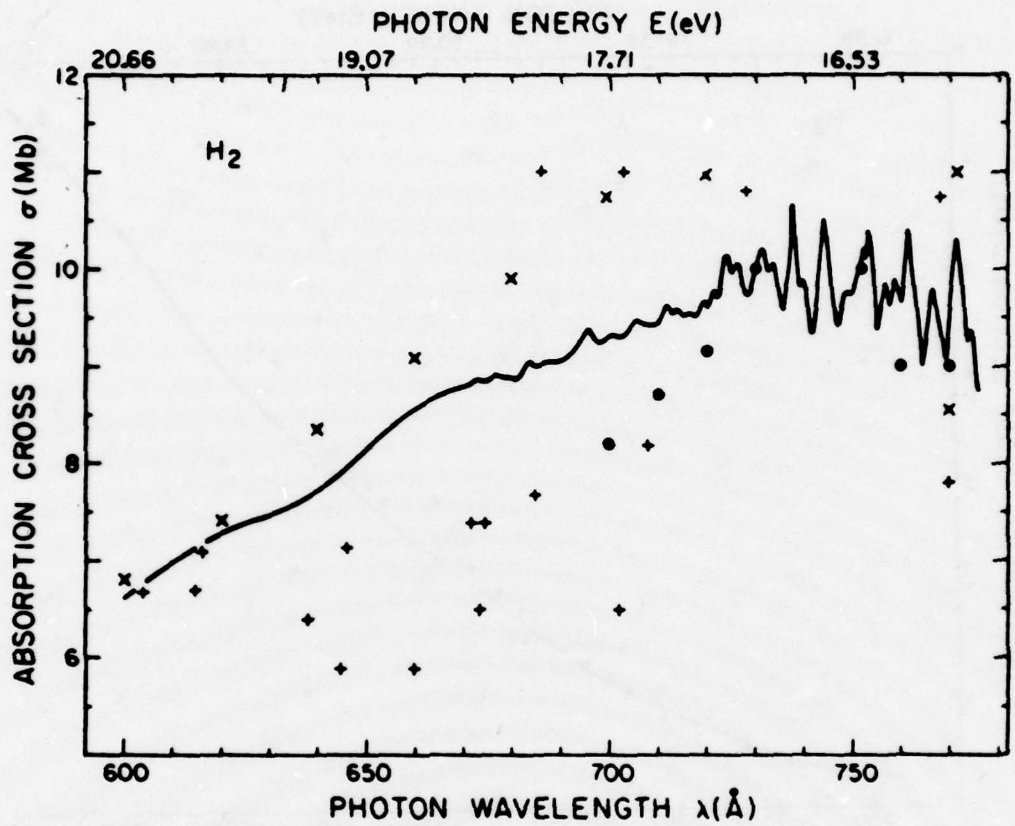
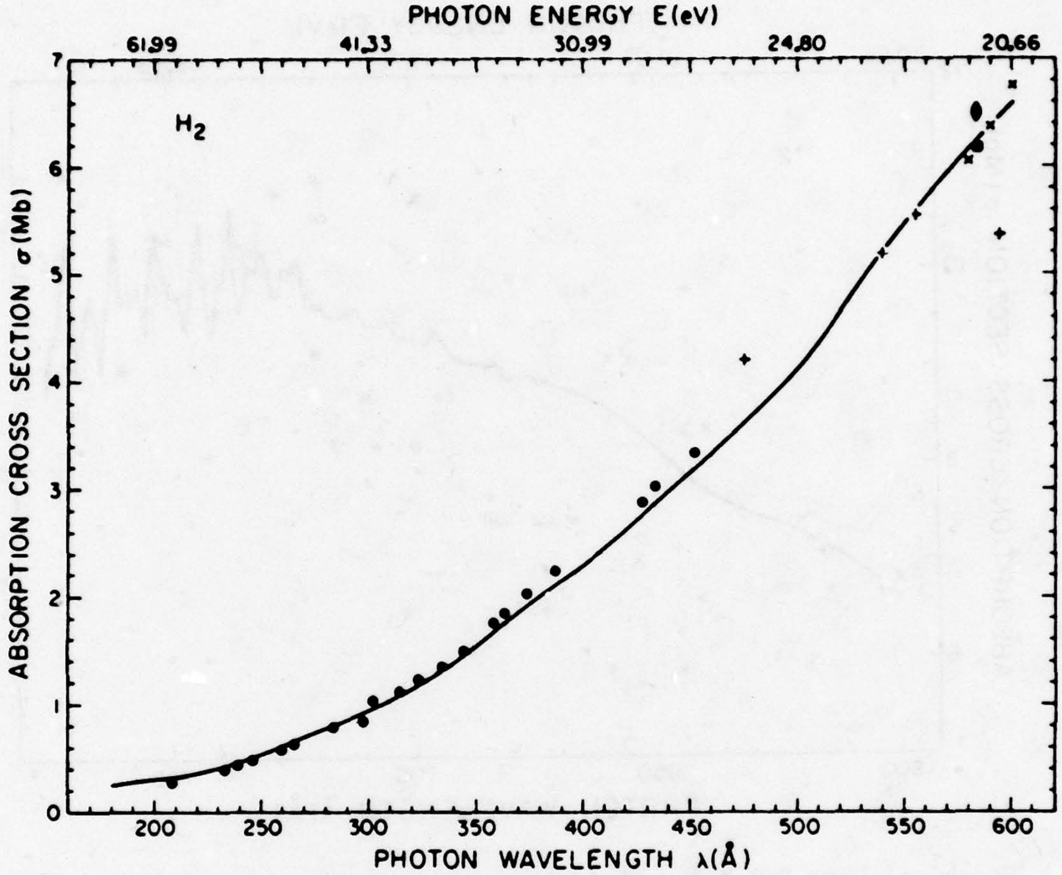
Tabular Data D-2.B-1. Photoabsorption cross sections of H_2 and D_2 (units of $10^{-18} cm^2$).

λ(Å)	H_2 σ(Mb)	D_2 σ(Mb)	λ(Å)	H_2 σ(Mb)	D_2 σ(Mb)
180	0.25	0.26	440	3.0	3.0
190	0.28	0.28	450	3.2	3.2
200	0.31	0.31	460	3.3	3.3
210	0.33	0.34	470	3.5	3.5
220	0.36	0.36	480	3.7	3.7
230	0.40	0.40	490	3.9	3.9
240	0.46	0.45	500	4.1	4.1
250	0.53	0.50	510	4.4	4.4
260	0.62	0.56	520	4.6	4.6
270	0.70	0.63	530	4.9	4.8
280	0.78	0.70	540	5.2	5.0
290	0.85	0.80	550	5.5	5.3
300	0.93	0.89	560	5.7	5.5
310	1.0	1.0	570	5.9	5.8
320	1.1	1.1	580	6.2	6.1
330	1.3	1.3	590	6.4	6.4
340	1.4	1.4	600	6.6	6.8
350	1.5	1.6	610	7.0	7.2
360	1.7	1.8	620	7.3	7.5
370	2.0	2.0	630	7.5	7.7
380	2.0	2.1	640	7.7	7.9
390	2.2	2.3	650	8.2	8.2
400	2.3	2.4	660	8.6	8.6
410	2.5	2.5	670	8.8	8.9
420	2.6.	2.7	680	8.9	9.2
430	2.8	2.8	690	9.1	9.6
			700	9.3	9.9

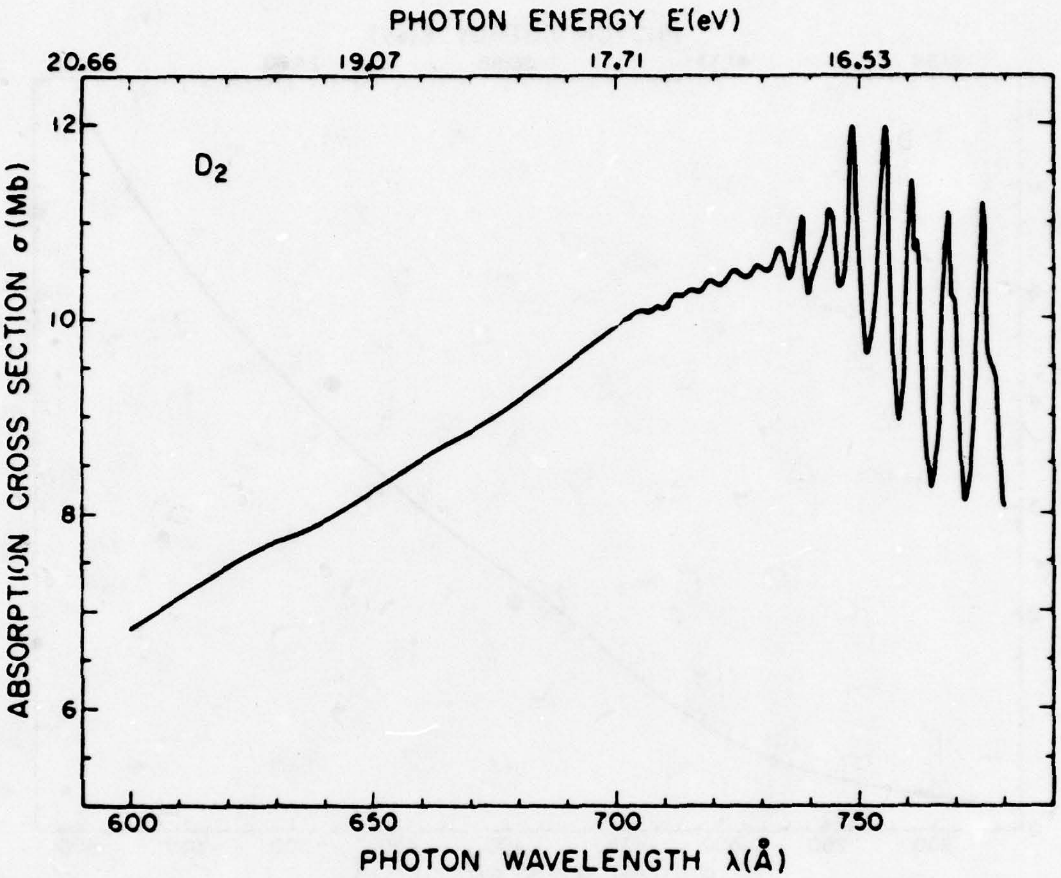
Reference: These data were taken from L. C. Lee, R. W. Carlson, and D. L. Judge, J. Quant. Spectrosc. Radiat. Transfer <u>16</u>, 873 (1976).



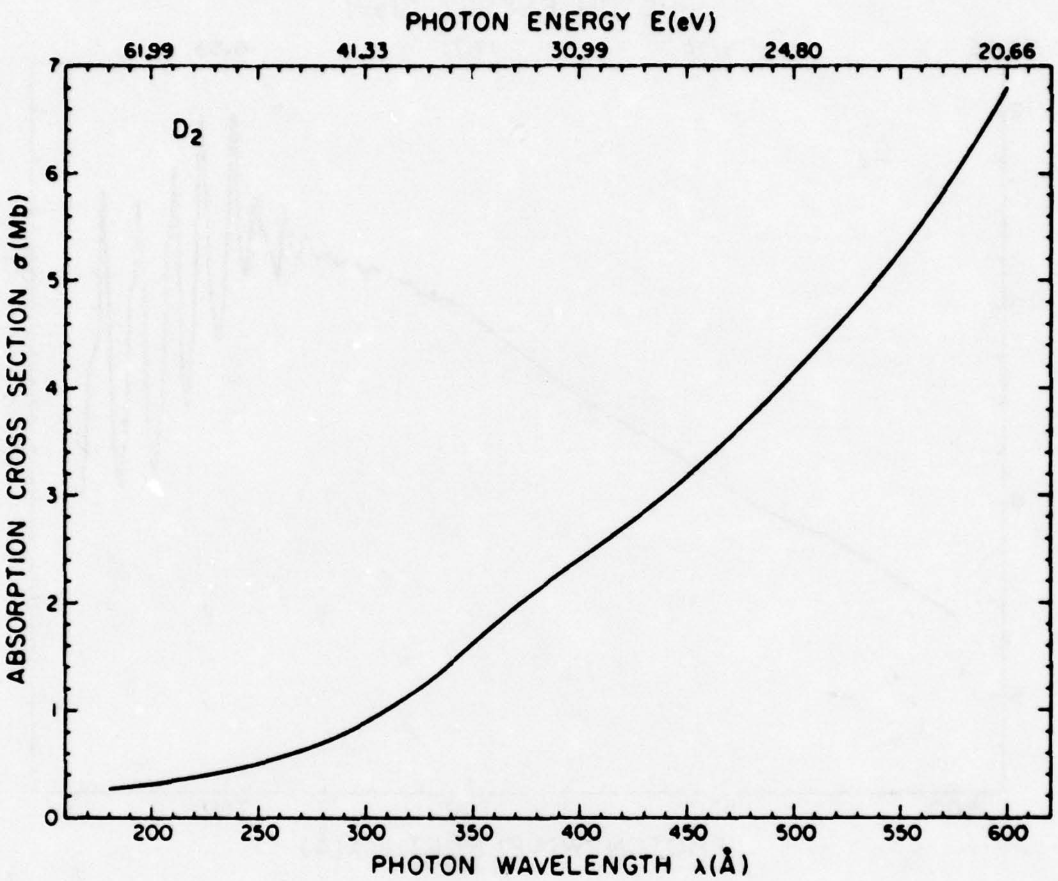
Graphical Data D-2.B-2. Photoabsorption cross section for H_2. This figure was taken from L. C. Lee, R. W. Carlson, and D. L. Judge, J. Quant. Spectrosc. Radiat. Transfer 16, 873 (1976). The solid line is the data of the above paper. The other data are from:
x - G. R. Cook and P. H. Metzger, J. Opt. Soc. Am. 54, 968 (1964):
• - J. E. Mentall and E. P. Gentieu, J. Chem. Phys. 52, 5641 (1970);
+ - P. Lee and G. L. Weissler, Astrophys. J. 115, 570 (1952).



Graphical Data D-2.B-3. Photoabsorption cross section for H_2. This figure was taken from L. C. Lee, R. W. Carlson, and D. L. Judge, J. Quant. Spectorsc. Radiat. Transfer 16, 873 (1976). The solid line is the data of the above paper. The other data are from:
● - J. A. R. Samson and R. B. Carins, J. Opt. Soc. Am. 55, 1035 (1965);
▲ - S. W. Bennett, J. B. Tellinghuisen, and L. F. Phillips, J. Chem. Phys. 75, 719 (1971); ■ - W. L. Starr and M. Lowenstein, J. Geophys. Res. 77, 4790 (1972); ▼ - J. E. Brolley, L. E. Porter, R. H. Sherman, J. K. Theobald, and J. C. Fong, J. Geophys. Res. 78, 1627 (1973);
x - G. R. Cook and P. H. Metzger, J. Opt. Soc. Am. 54,968 (1964);
+ - P. Lee and G. L. Weissler, Astrophys. J. 115, 570 (1952).



Graphical Data D-2.B-4. Photoabsorption cross section for D_2. These data were taken from L. C. Lee, R. W. Carlson, and D. L. Judge, J. Quant. Spectrosc. Radiat. Transfer 16, 873 (1976).

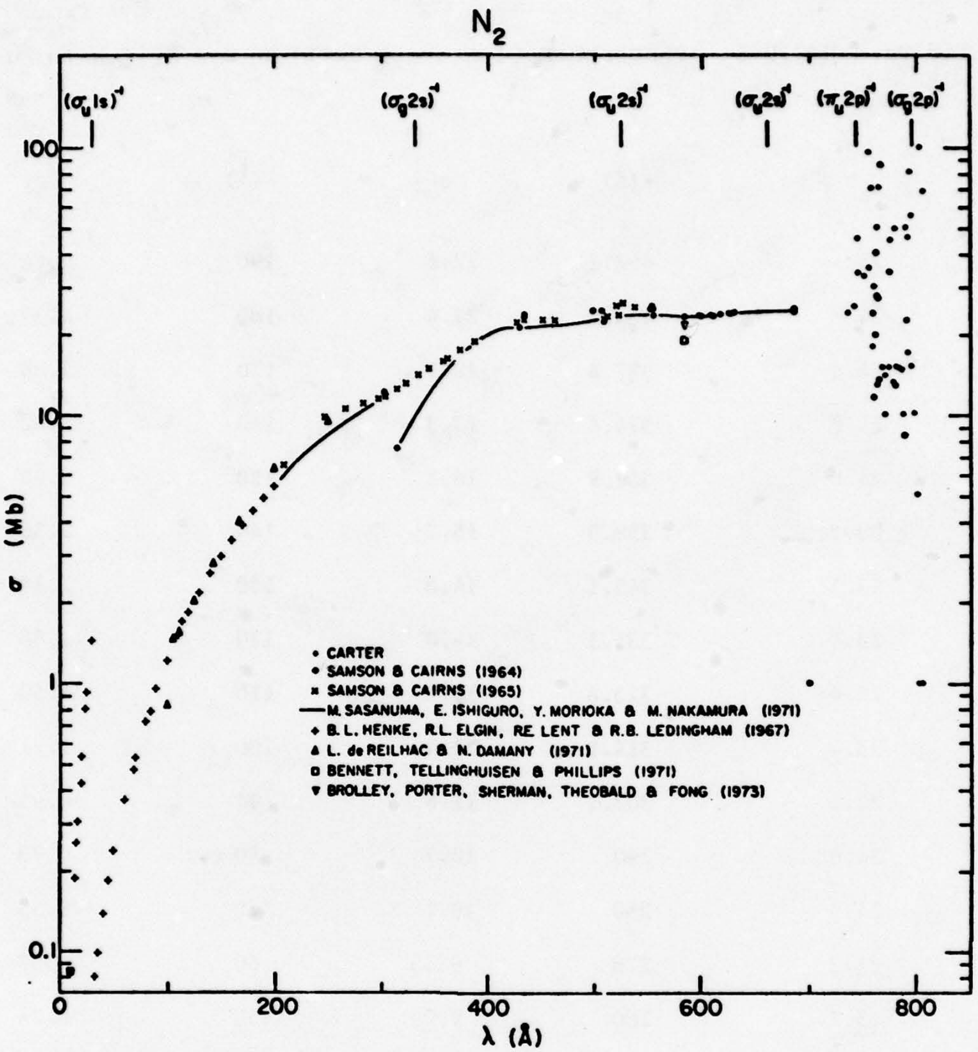


Graphical Data D-2.B-5. Photoabsorption cross section for D_2. These data were taken from L. C. Lee, R. W. Carlson, and D. L. Judge, J. Quant. Spectrosc. Radiat. Transfer 16, 873 (1976).

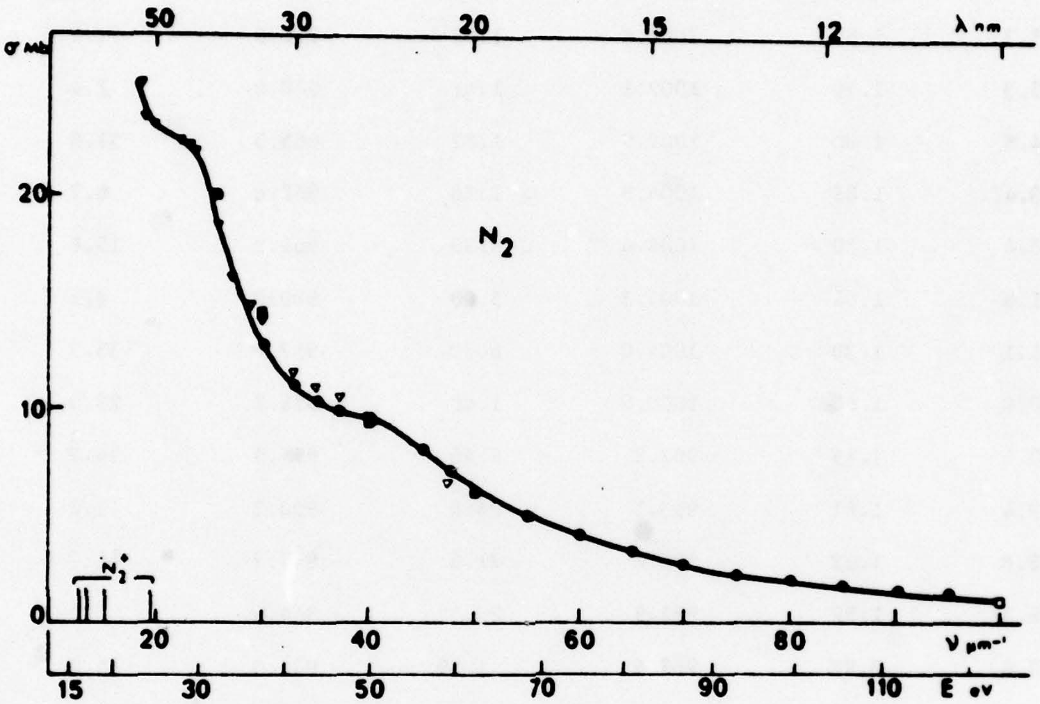
Tabular Data D-2.B-6. Photoabsorption cross section for N_2 (units of 10^{-18} cm^2).

λ(Å)	σ	λ(Å)	σ	λ(Å)	σ
740	25	452.2	22.6	190	4.88
735	24	434.3	22.4	180	4.37
685	24.4	387.4	18.6	170	3.86
629.7	24.2	374.4	17.3	160	3.40
625.8	24.0	362.9	16.1	150	2.98
617	23.7	358.5	15.7	140	2.56
610.8	23.3	345.1	14.8	130	2.18
608.4	23.4	335.1	14.0	120	1.83
599.6	23.4	323.6	13.1	110	1.50
597.8	23.4	314.9	12.4	100	1.21
584.3	23.1	303.1	11.6	90	0.95
555.3	24.8	290	10.7	80	0.73
554.5	24.6	280	10.1	70	0.53
554.0	25.3	270	9.55	60	0.37
537	25.2	260	9.00	50	0.24
525.8	26.2	250	8.40	40	0.138
522.2	23.6	240	7.75	35	0.099
519.6	25.8	230	7.20	30	1.43
512.1	23.2	220	6.70	25	0.926
508.2	22.8	210	6.10	20	0.535
463.7	22.6	200	5.40	15	0.256

Reference: This table was derived from many individual measurements by J. Berkowitz, Photoabsorption, Photoionization, and Photoelectron Spectroscopy (copyright Academic Press, Inc., 1979); reproduced by permission.



Graphical Data D-2.B-7. Experimental photoabsorption cross section of N_2. The data are from: ● - V. L. Carter, J. Chem. Phys. 56, 4195 (1972); o - J. A. R. Samson and R. B. Cairns, J. Geophys. Res. 69, 4583 (1964); x - J. A. R. Samson and R. B. Cairns, J. Opt. Soc. Am. 55, 1035 (1965); — - M. Sasanuma, E. Ishiguro, U. Morioka and M. Nakamura, III[rd] Int'l Conf. on VUV Radiation Physics, Tokyo (1971), paper 1 p. A2-3; + - B. L. Henke, R. L. Elgin, R. E. Lent and R. B. Ledingham, Norelco Reporter 14, 112 (1967); Δ - L. de Reilhac and N. Damany, J. de Physique, Coll. C4, 32. C4-32 (1971); ■ - S. W. Bennett, J. B. Tellinghuisen and L. F. Phillips, J. Phys. Chem. 75, 719 (1971); ▼ - J. E. Brolley, L. E. Porter, R. H. Sherman, J. K. Theobald and J. C. Fong, J. Geophys. Res. 78, 1627 (1973). This figure was taken from J. Berkowitz, Photoabsorption, Photoionization, and Photoelectron Spectroscopy (copyright Academic Press, Inc.); reproduced by permission.



Graphical Data D-2.B-8. Photoabsorption cross section for N_2. This figure was taken from L. de Reilhac and N. Damany, J. Quant. Spectrosc. Radiat. Transfer 18, 121 (1977). The data are from: ● - above paper; ∇ - J. A. R. Samson and R. B. Cairns, J. Opt. Soc. Am. 55, 1035 (1965); ■ - L. C. Lee, R. W. Carlson, D. L. Judge, and M. Ogawa, J. Quant. Spectrosc. Radiat. Transfer 13, 1023 (1973).

Tabular Data D-2.B-9. Photoabsorption cross section of O_2 (units of 10^{-18} cm^2).

λ(Å)	σ	λ(Å)	σ	λ(Å)	σ
1028.1	0.67	1011.4	1.30	972.9	42.8
1025.7	1.64	1009.4	1.52	972.5	31.6
1025.3	1.79	1009.1	1.41	970.4	2.4
1024.6	1.00	1007.9	1.82	965.5	51.0
1023.4	1.86	1006.8	1.38	962.8	6.7
1022.4	1.30	1004.6	6.30	961.9	15.6
1021.6	1.64	1004.3	5.60	960.0	2.5
1021.1	1.30	1004.0	6.30	957.0	35.3
1020.8	1.60	1000.0	1.49	956.7	29.0
1020.4	1.19	997.2	1.45	955.9	54.7
1019.4	1.41	993.5	24.5	950.3	2.2
1018.8	1.08	993.2	21.6	947.7	56.2
1018.3	1.52	992.9	23.4	944.6	2.6
1017.8	0.97	989.6	1.50	939.3	45.0
1017.2	1.60	988.5	4.80	935.6	2.8
1016.9	1.08	988.0	3.00	932.4	28.6
1016.4	1.38	985.9	7.40	931.5	12.3
1016.0	1.19	985.2	4.80	930.6	26.0
1015.8	1.75	983.3	46.1	930.0	3.7
1013.9	1.12	980.5	2.4	929.1	4.1
1013.5	1.34	975.3	26.8	928.1	3.3
1012.3	1.08	974.5	5.6	927.6	4.1

Tabular Data D-2.B-9. Photoabsorption cross section of O_2 (Continued).

λ(Å)	σ	λ(Å)	σ	λ(Å)	σ
926.4	3.7	885.8	17.9	838.6	24.5
24.5	23.4	83.3	4.8	37.8	11.2
23.5	8.9	78.1	13.4	36.3	17.1
23.1	9.7	75.2	5.6	35.4	10.0
20.4	3.0	71.4	10.0	34.5	10.8
17.2	23.4	70.0	8.2	34.1	10.4
15.6	4.1	67.6	5.6	32.5	32.7
14.7	7.4	64.6	9.3	31.0	10.8
13.5	4.8	61.0	7.4	29.8	23.1
10.5	17.5	59.2	6.7	29.6	22.3
10.0	15.2	57.3	10.0	29.4	22.7
09.6	17.1	55.0	7.1	28.3	11.2
06.4	4.1	53.2	12.6	27.8	12.3
03.8	10.8	51.8	8.6	26.8	11.9
02.0	9.7	50.6	9.7	26.0	29.0
01.1	13.4	49.2	7.4	25.3	20.1
900.2	8.9	48.5	7.8	24.9	24.2
898.7	4.8	47.6	7.4	24.1	16.0
97.3	7.4	45.9	18.6	23.2	28.3
95.8	5.6	44.6	10.0	21.3	16.0
94.0	11.2	43.8	12.3	19.8	31.6
93.1	5.6	42.1	8.2	18.2	20.1
91.6	10.8	39.1	24.9	17.2	45.4
89.1	4.8	38.9	23.4	14.9	18.6

Tabular Data D-2.B-9. Photoabsorption cross sections for O_2 (Continued).

λ(Å)	σ	λ(Å)	σ	λ(Å)	σ
813.7	35.0	787.6	25.7	765.4	22.3
12.5	29.4	86.4	19.7	64.6	17.5
11.8	55.0	86.0	26.8	63.2	21.9
09.3	22.3	84.8	23.8	62.5	19.3
08.2	36.4	84.4	25.7	62.1	19.7
07.0	27.9	83.2	20.5	61.5	19.3
05.1	49.1	82.9	20.8	60.7	21.2
03.5	26.0	81.5	14.5	59.4	17.1
02.6	34.2	80.0	27.9	58.4	19.3
801.6	27.2	78.8	24.5	58.0	17.5
799.5	39.8	78.1	29.4	56.2	19.3
98.1	26.8	75.1	13.8	56.0	19.0
97.7	31.6	73.1	26.8	55.0	23.4
96.0	21.9	72.4	23.8	52.9	14.9
95.2	23.4	71.6	24.2	51.6	19.0
95.0	23.1	70.8	19.7	51.0	17.5
94.1	33.8	70.5	20.5	50.0	23.8
92.8	24.2	70.2	15.2	48.0	15.6
92.4	27.9	69.6	21.2	47.0	21.2
91.3	21.2	69.2	17.9	46.4	18.6
90.0	28.3	68.8	20.8	45.0	20.5
89.0	26.8	68.4	17.1	43.2	17.9
88.6	27.5	67.3	20.1	42.2	21.6
88.0	24.2	66.7	19.0	41.2	20.1

Tabular Data D-2.B-9. Photoabsorption cross sections for O_2 (Continued).

λ(Å)	σ	λ(Å)	σ	λ(Å)	σ
740.0	25.7	717.6	29.8	695.2	30.5
39.3	24.9	17.2	27.5	94.0	18.2
37.5	34.2	16.5	30.5	92.4	34.6
37.2	32.4	16.0	29.0	91.3	17.9
35.3	35.3	14.7	35.0	90.1	26.0
33.3	32.7	14.0	33.1	89.1	16.4
32.5	51.3	12.9	37.9	88.7	20.8
31.8	31.6	11.9	32.4	87.9	16.7
31.1	35.3	11.0	41.7	86.6	23.8
29.8	29.0	09.7	25.7	86.1	16.7
29.4	29.8	09.3	26.8	84.9	27.2
29.0	27.9	08.9	25.7	83.8	17.5
28.3	30.5	07.9	26.4	82.8	21.9
27.3	30.1	06.6	24.9	82.3	18.6
26.4	49.1	05.3	63.2	81.6	22.3
25.0	25.3	03.6	26.0	81.4	21.9
24.2	27.5	03.1	29.0	81.1	22.3
23.4	25.3	01.6	19.0	80.7	19.3
22.9	26.0	700.8	35.0	79.9	23.8
22.6	25.7	699.6	23.4	79.2	18.2
21.8	27.5	98.3	34.6	77.0	21.2
21.3	26.8	97.7	31.6	76.6	20.1
20.4	34.2	97.3	30.5	76.2	21.6
19.4	24.9	96.0	19.3	75.7	20.1

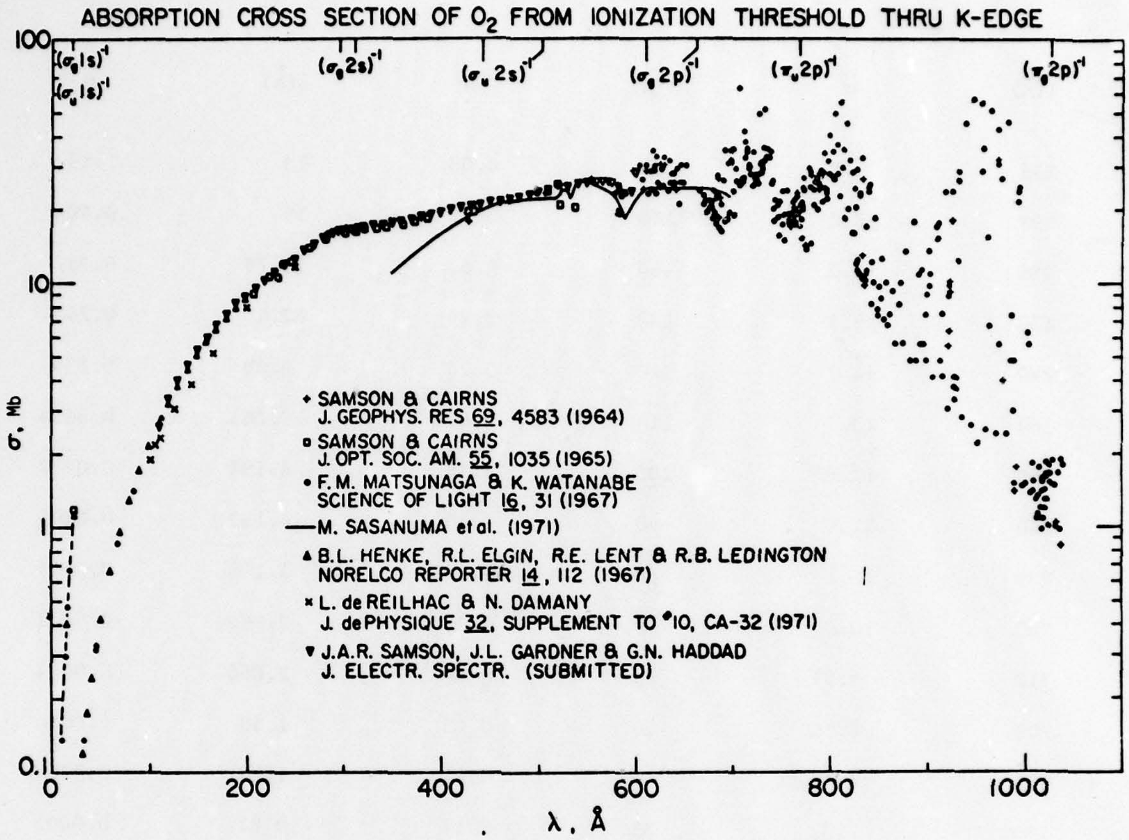
Tabular Data D-2.B-9. Photoabsorption cross sections for O_2 (Continued).

λ(Å)	σ	λ(Å)	σ	λ(Å)	σ
675.0	21.6	621.9	32.7	530	24.9
73.6	19.3	20.5	23.1	520	24.5
70.5	21.6	18.7	29.8	510	24.0
70.0	20.8	18.2	28.3	500	23.6
69.6	22.7	17.7	34.6	490	23.0
65.8	23.8	16.3	24.2	480	22.6
51.8	29.8	15.2	28.6	470	22.1
49.4	25.3	13.1	28.3	460	21.7
46.7	30.1	12.7	23.1	450	21.4
45.9	24.9	10.8	30.1	440	21.0
45.0	25.3	08.9	26.4	430	20.7
44.2	20.8	604.3	30.1	420	20.3
42.5	29.0	600	28.6	410	20.0
38.7	25.3	595	23.8	400	19.6
38.1	27.9	590	19.4	390	19.2
37.3	25.3	585	22.4	380	18.8
36.3	27.9	580	24.8	370	18.4
35.8	25.3	575	25.5	360	18.0
34.4	31.2	570	25.8	350	17.8
33.0	23.4	565	26.0	340	17.5
29.6	32.4	560	26.1	330	17.3
27.1	24.9	555	26.1	320	17.2
26.6	29.0	550	25.9	310	17.0
624.5	25.3	540	25.4	300	16.7

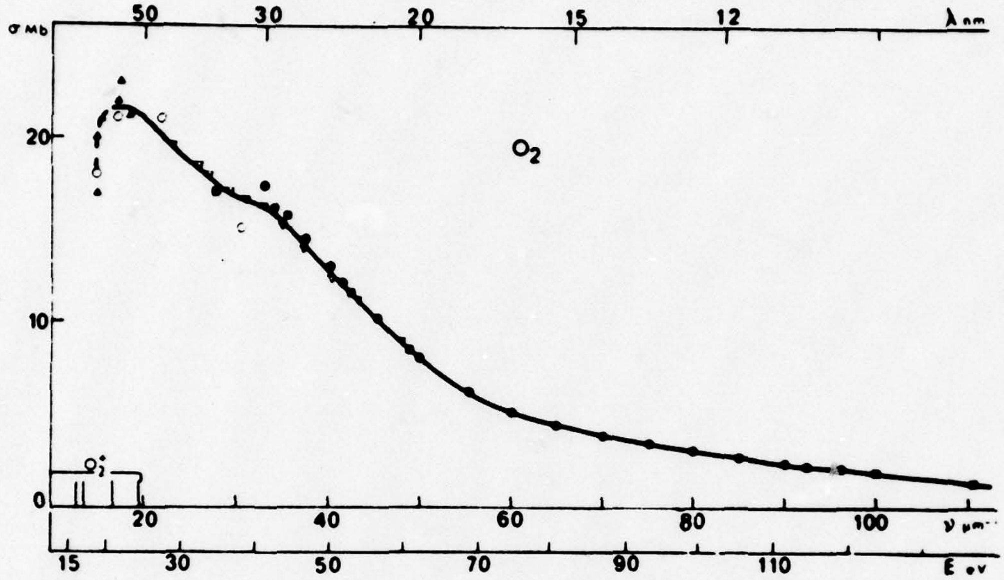
Tabular Data D-2.B-9. Photoabsorption cross sections for O_2 (Concluded).

λ(Å)	σ	λ(Å)	σ	λ(Å)	σ
295	16.5	160	6.03	23	1.15
290	16.2	150	5.32	15	0.404
285	15.9	140	4.62	13.78	0.312
280	15.5	130	3.95	12.40	0.245
270	14.7	120	3.24	9.89	0.135
260	13.7	110	2.61	8.265	0.0834
250	12.8	100	2.16	6.199	0.0372
240	11.9	90	1.70	4.133	0.0105
230	11.1	80	1.30	3.100	0.0049
220	10.3	70	0.95	2.480	0.0025
210	9.57	60	0.66	2.066	0.0014
200	8.86	50	0.42	1.55	0.0006
190	8.15	40	0.24	1.24	0.0004
180	7.33	35	0.17	0.827	0.0001
170	6.70	30	0.11	0.620	0.0000

Reference: This table was derived from many individual measurements by J. Berkowitz, Photoabsorption, Photoionization, and Photoelectron Spectroscopy (copyright Academic Press, Inc., 1979); reproduced by permission.



Graphical Data D-2.B-10. Experimental photoabsorption cross section of O_2. The data are from: + - J. A. R. Samson and R. B. Cairns, J. Geophys. Res. 69, 4583 (1964); □ - J. A. R. Samson and R. B. Cairns, J. Opt. Soc. Am. 55, 1035 (1965); • - F. M. Matsunaga and K. Watanabe, Science of Light 16, 31 (1967); — - M. Sasanuma, E. Eshiguro, Y. Morioka and M. Nakamura, IIIrd Int'l. Conf. on VUV Radiation Physics, Tokyo (1971), paper 1 p. A2-3; ▲ - B. L. Henke, R. L. Elgin, R. E. Lent and R. B. Ledingham, Norelco Reporter 14, 112 (1967); x - L. de Reilhac and N. Damany, J. de Physique Coll. C4 32, C4-32 (1971); ▼ - J. A. R. Samson, J. L. Gardner and G. N. Haddad, J. Electr. 12, 281 (1977). This figure was taken from J. Berkowitz, Photoabsorption, Photoionization, and Photoelectron Spectroscopy (copyright Academic Press, Inc. 1979); reproduced by permission.



Graphical Data D-2.B-11. Photoabsorption cross section for O_2. This figure was taken from L. de Reilhac and N. Damany, J. Quant. Spectrosc. Radiat. Transfer 18, 121 (1977). The data are from ● - above paper; ○ - P. Lee, J. Opt. Soc. Am. 45, 703 (1955); ▲ - F. M. Matsunaga and K. Watanabe, Sci. Light (Tokyo) 16, 31 (1967); ▼ - J. A. R. Samson and R. B. Cairns, J. Opt. Soc. Am. 55, 1035 (1965); ■ - L. C. Lee, R. W. Carlson, D. L. Judge, and M. Ogawa, J. Quant. Spectrosc. Radiat. Transfer 13, 1023 (1973).

Section D-2.C. PHOTOABSORPTION CROSS SECTIONS FOR CH_4, CO, CO_2, ClO, O_3, HCl, H_2O, D_2O, $HgBr_2$, HgI_2, ICN, NH_3, N_2O, NO, NO_2, and UF_6

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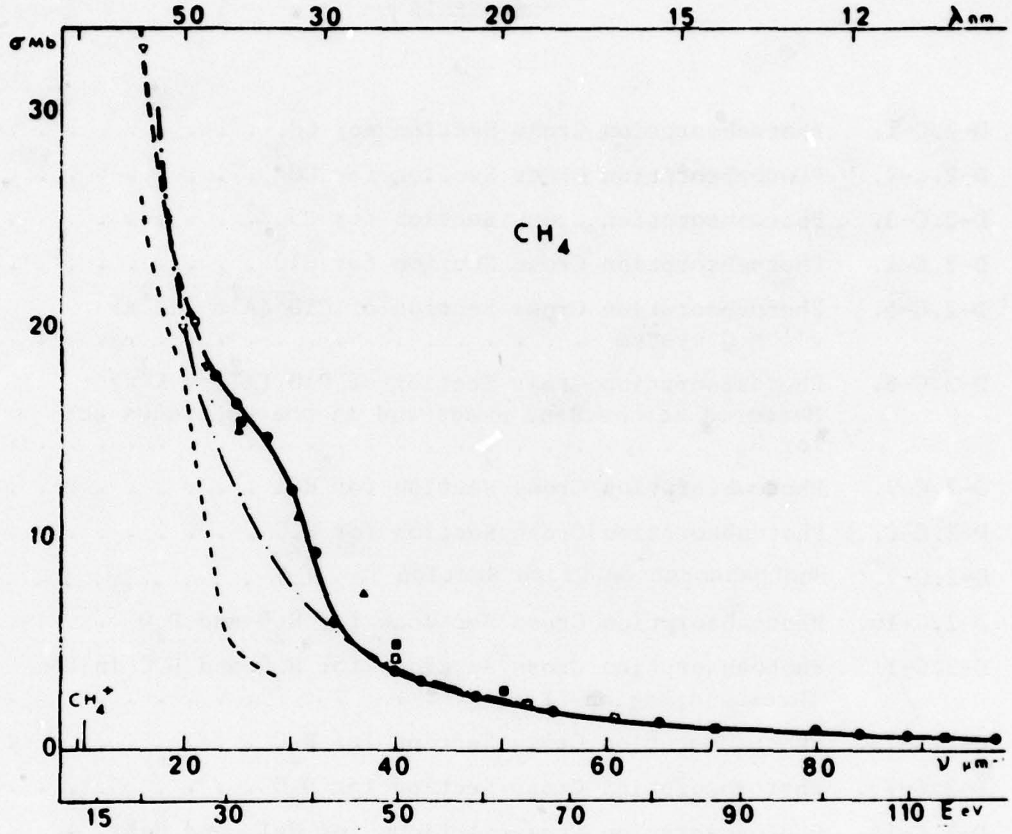
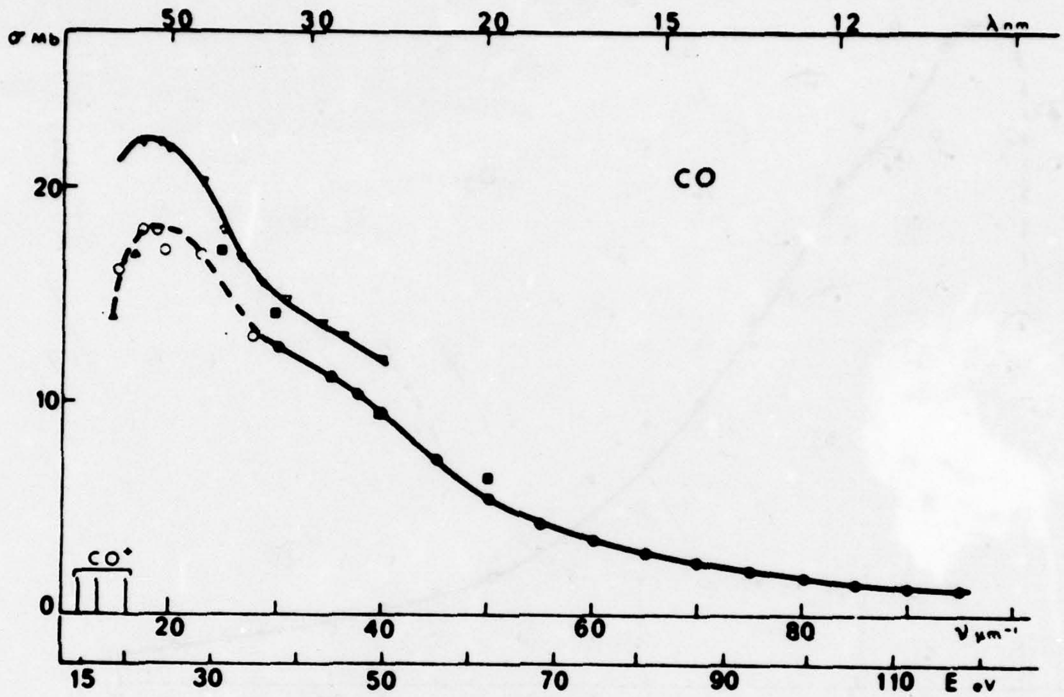
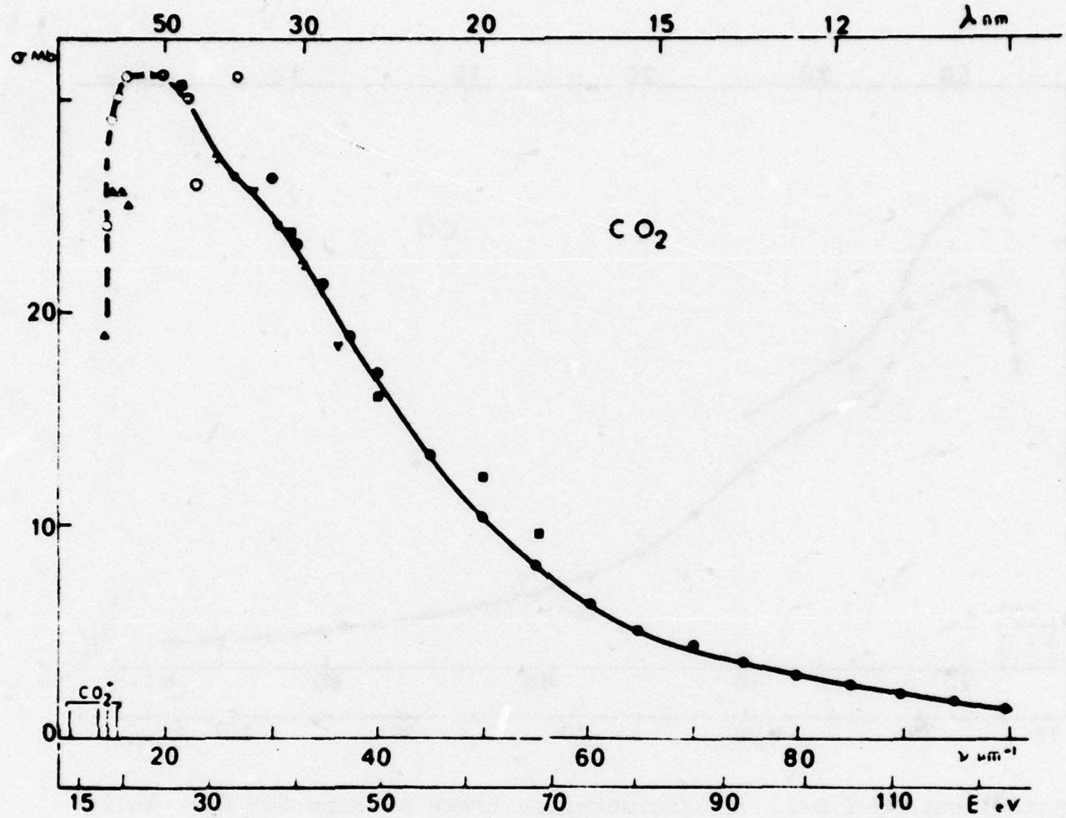


Graphical Data D-2.C-1. Photoabsorption cross section for CH_4. This figure was taken from L. de Reilhac and N. Damany, J. Quant. Spectrosc. Radiat. Transfer 18, 121 (1977); the data are a composite of eight different references cited therein.



Graphical Data D-2.C-2. Photoabsorption cross section for CO. This figure was taken from L. de Reilhac and N. Damany, J. Quant. Spectrosc. Radiat. Transfer 18, 121 (1977). The data are from: ● - above paper; ○ - H. Sun and G. L. Weissler, J. Chem. Phys. 23, 1625 (1955); ▼ - R. B. Cairns and J. A. R. Samson, J. Opt. Soc. Am. 56, 526 (1966); ■ - L. C. Lee, R. W. Carlson, D. L. Judge, and M. Ogawa, J. Quant. Spectrosc. Radiat. Transfer 13, 1023 (1973).

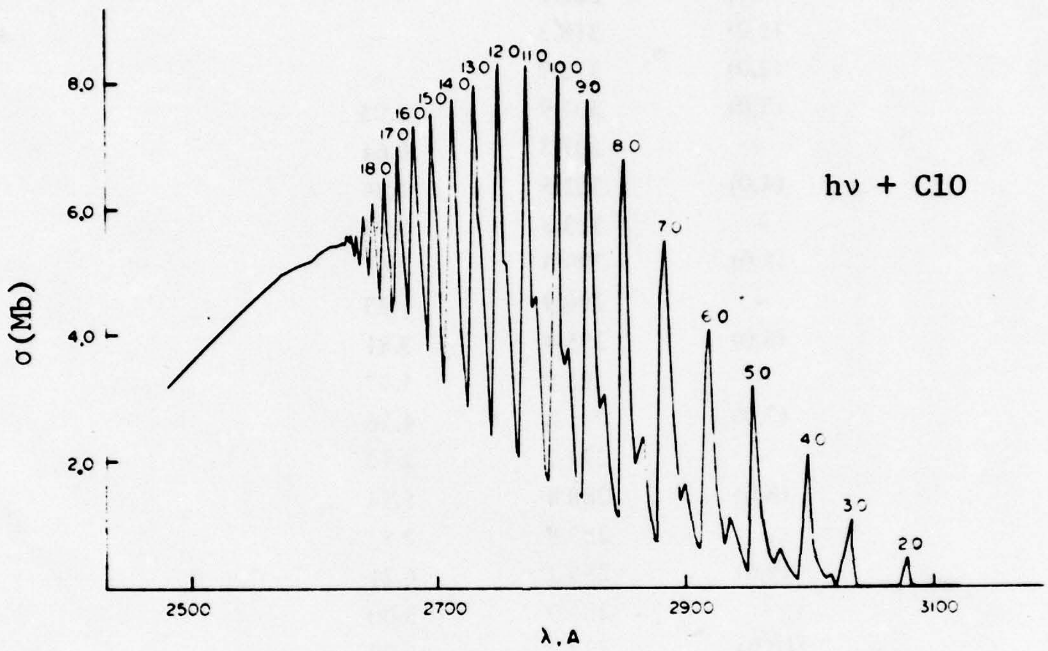


Graphical Data D-2.C-3. Photoabsorption cross section for CO_2. This figure was taken from L. de Reilhac and N. Damany, J. Quant. Spectrosc. Radiat. Transfer 18, 121 (1977). The data are from: ● - above paper; o - H. Sun and G. L. Weissler, J. Chem. Phys. 23, 1372 (1955); ▲ - G. R. Cook, P. H. Metzger, and M. Ogawa, J. Chem. Phys. 44, 2935 (1966); ▽ - R. B. Cairns and J. A. R. Samson, J. Opt. Soc. Am. 56, 526 (1966); ■ - L. C. Lee, R. W. Carlson, D. L. Judge, and M. Ogawa, J. Quant. Spectrosc. Radiat. Transfer 13, 1023 (1973).

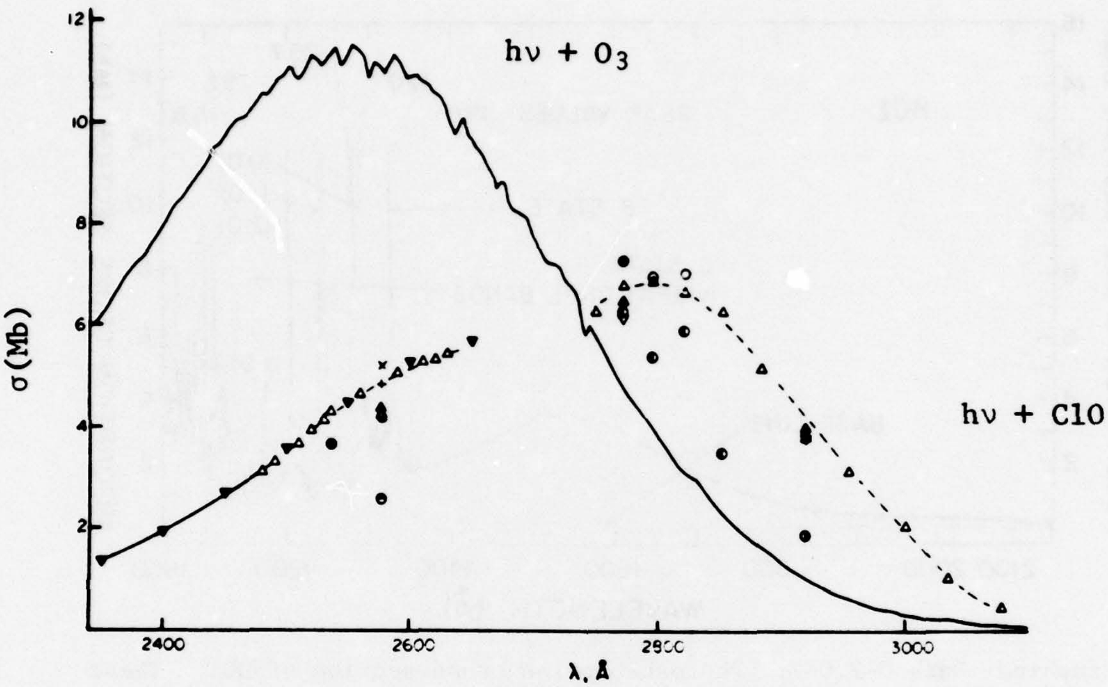
Tabular Data D-2.C-4. Photoabsorption cross sections for ClO (units of 10^{-8} cm^2)

Band heads	λ (nm)	σ (10^{-18} cm^2)
(0,0)	323.9	–
(1,0)	318.3	–
(2,0)	312.7	–
(3,0)	307.9	1.03
–	307.3	0.64
(4,0)	303.5	1.84
–	303.2	0.99
(5,0)	299.3	2.61
–	298.9	1.33
(6,0)	295.4	3.81
–	295.0	1.77
(7,0)	291.8	4.16
–	291.2	2.12
(8,0)	288.4	5.14
–	287.8	2.53
(9,0)	285.2	6.21
–	284.9	3.00
(10,0)	282.2	6.98
–	281.9	3.14
(11,0)	279.6	7.03
–	279.2	3.19
(12,0)	277.2	7.20
–	276.8	3.34
(13,0)	275.0	7.41
–	274.6	3.77
(14,0)	272.9	7.22
–	272.6	3.90

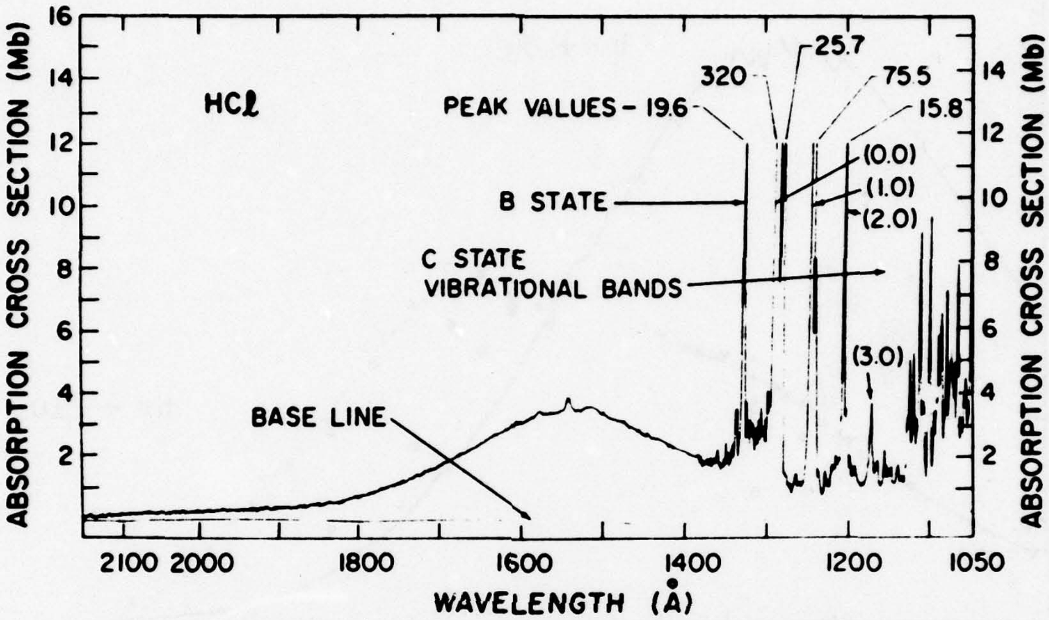
Reference: The data were taken from P. Rigaud, B. Leroy, G. LeBras, G. Poulet, J. L. Jordain, and J. Combourieu, Chem. Phys. Letts. 46, 161 (1977).



Graphical Data D-2.C-5. Photoabsorption cross section of ClO ($A^2\pi \rightarrow X^2\pi$) v'' = 0 system. The data were taken from M. Mandelman and R. W. Nicholls, J. Quant. Spectrosc. Radiat. Transfer 17, 483 (1972).



Graphical Data D-2.C-6. Photoabsorption cross section of ClO ($A^2\pi \rightarrow X^2\pi$) measured at the band heads and in the continuum and for O_3. This figure was taken from M. Mandelman and R. W. Nichols, J. Quant. Spectrosc. Radiat. Transfer 17, 483 (1977) which cites the 14 original sources of the above data.



Graphical Data D-2.C-7. Photoabsorption cross section of HCl. These data were taken from J. A. Myer and J. A. R. Samson, J. Chem. Phys. 52, 266 (1970).

Tabular Data D-2.C-8. Photoabsorption cross section for H_2O (units 10^{-18} cm^2).

λ(Å)	σ	λ(Å)	σ
980.6	16.7	933.7	24.3
978.0	15.1	932.4	24.0
977.2	15.1	930.0	19.3
973.6	15.0	927.4	23.4
972.5	15.1	926.2	25.4
970.0	13.8	923.8	22.5
968.3	17.7	917.5	24.1
967.3	17.6	916.6	25.7
965.4	16.7	915.5	22.5
963.3	17.8	911.5	21.1
960.8	17.7	910.0	23.2
959.7	19.4	909.0	24.2
958.2	18.6	908.1	24.0
952.1	20.2	905.0	19.1
951.0	20.2	900.4	24.2
949.4	20.6	894.4	22.8
948.0	20.0	892.9	23.7
945.3	20.6	891.4	21.6
943.4	21.8	885.8	22.6
942.6	24.1	883.3	20.5
941.2	22.9	879.0	21.7
936.3	22.0	877.7	20.5
934.8	23.5	874.1	20.5

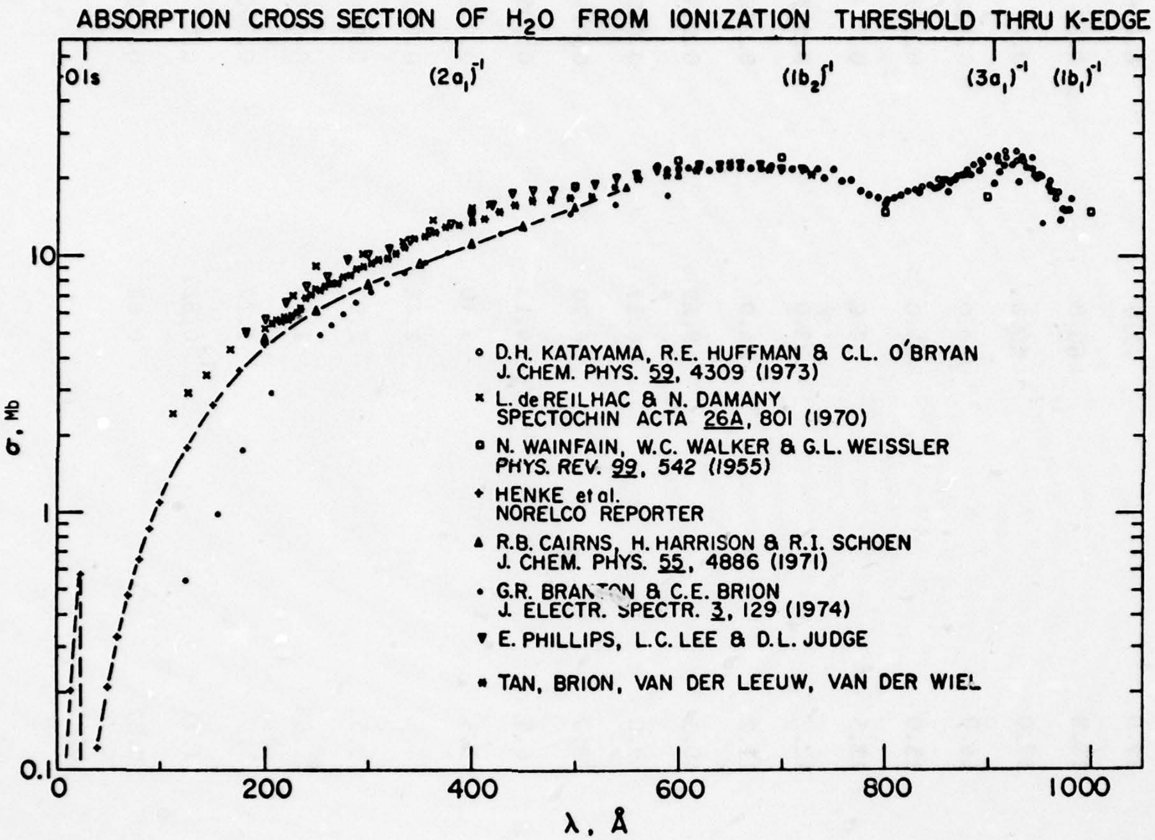
Tabular Data D-2.C-8. Photoabsorption cross sections for H_2O (Continued).

λ(Å)	σ	λ(Å)	σ
872.3	20.6	766.6	19.5
870.2	20.5	758.7	19.3
867.9	19.9	750.0	21.7
866.8	19.8	742.0	20.0
864.8	19.7	734.5	21.8
862.5	19.1	722.8	21.8
861.0	17.8	700.0	21.4
859.2	19.7	695.5	22.2
857.4	19.8	693.0	21.7
855.2	18.8	689.0	22.2
852.6	18.6	686.0	21.7
851.0	19.8	683.0	22.2
848.8	18.3	680.0	21.6
844.0	18.8	677.0	22.3
836.5	18.6	670.0	21.9
833.7	17.6	660.0	22.0
829.6	18.0	650.0	22.0
822.2	17.7	640.0	21.6
815.8	17.1	630.0	21.4
808.7	16.8	620.0	22.0
802.5	16.4	610.0	22.0
800.0	16.0	600.0	21.5
793.6	16.7	590.0	21.5
784.0	17.2	580.0	22.2
776.7	17.8	550.0	20.0

Tabular Data D-2.C-8. Photoabsorption cross sections for H_2O (Concluded).

λ(Å)	σ	λ(Å)	σ
525.0	19.0	70.0	0.476
500.0	18.0	60.0	0.33
475.0	17.0	50.0	0.21
450.0	16.0	40.0	0.121
425.0	15.0	35.0	0.087
400.0	13.5	30.0	0.059
375.0	12.2	23.0	0.575
350.0	11.2	15.0	0.202
325.0	10.1	9.89	0.068
300.0	9.0	8.27	0.042
275.0	8.0	6.20	0.019
250.0	6.5	4.13	0.0057
225.0	5.5	3.10	0.0025
200.0	4.5	2.48	0.0012_5
175.0	3.53	2.07	0.00072
150.0	2.63	1.55	0.000296
125.0	1.8	1.24	0.000147
100.0	1.11	0.827	0.0000409
90.0	0.87	0.62	0.0000163
80.0	0.66		

Reference: This table was derived from many individual measurements by J. Berkowitz, Photoabsorption, Photoionization, and Photoelectron Spectroscopy (copyright Academic Press, Inc., 1979); reproduced by permission.

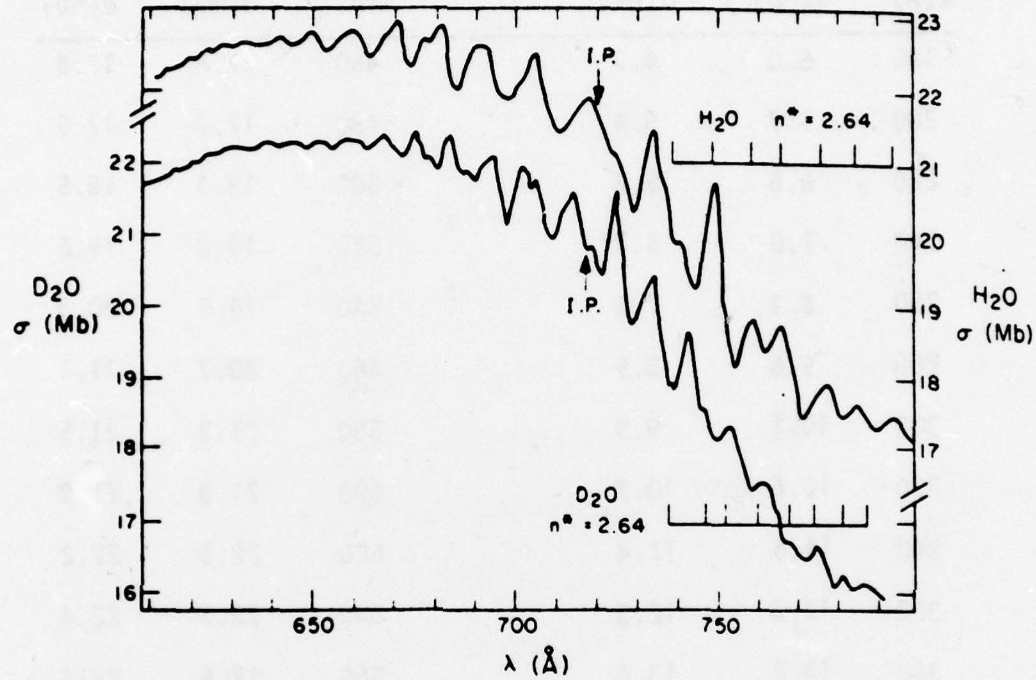


Graphical Data D-2.C-9. Experimental photoabsorption cross section of H_2O. Most references are given in the figure. The last two are E. Phillips, L. C. Lee, and D. L. Judge, J. Quant. Spectrosc. Radiat. Transfer 18, 309 (1977) and K. H. Tan, C. E. Brion, Ph. E. Van Der Leeuw, and M. J. Van der Weil, Chem. Phys. 29, 299 (1978). This figure was taken from J. Berkowitz, Photoabsorption, Photoionization, and Photoelectron Spectroscopy (copyright Academic Press, Inc.); reproduced by permission.

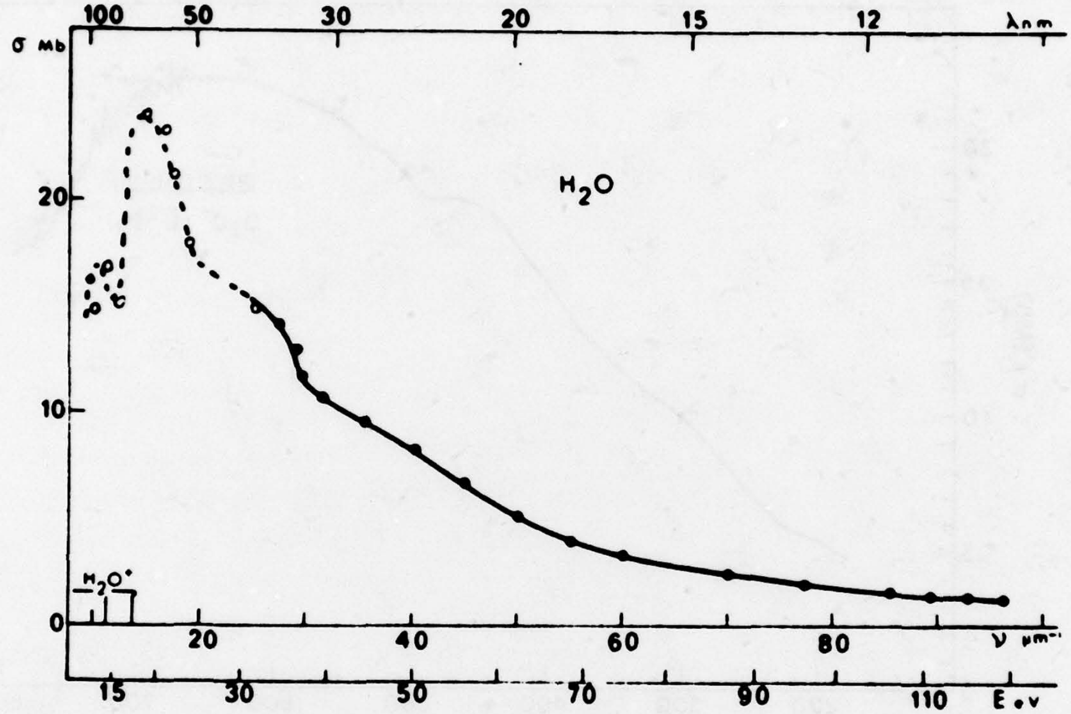
Tabular Data D-2.C-10. Photoabsorption cross sections for H_2O and D_2O (units of 10^{-18} cm^2).

λ(Å)	H_2O σ(Mb)	D_2O σ(Mb)	λ(Å)	H_2O σ(Mb)	D_2O σ(Mb)
180	5.0	4.7	460	17.8	17.8
200	5.7	5.4	480	17.7	17.9
220	6.6	5.8	500	18.3	18.6
240	7.6	6.7	520	19.0	19.6
260	8.3	7.8	540	19.9	20.3
280	9.6	8.9	560	20.7	21.1
300	10.1	9.9	580	21.3	21.5
320	10.6	10.7	600	21.9	21.9
340	11.5	11.4	620	22.5	22.2
360	12.3	12.3	640	22.7	22.4
380	13.2	13.4	660	22.8	22.4
400	14.3	14.8	680	22.7	22.0
420	15.6	16.2	700	21.9	21.4
440	17.2	17.4	720	21.8	20.7

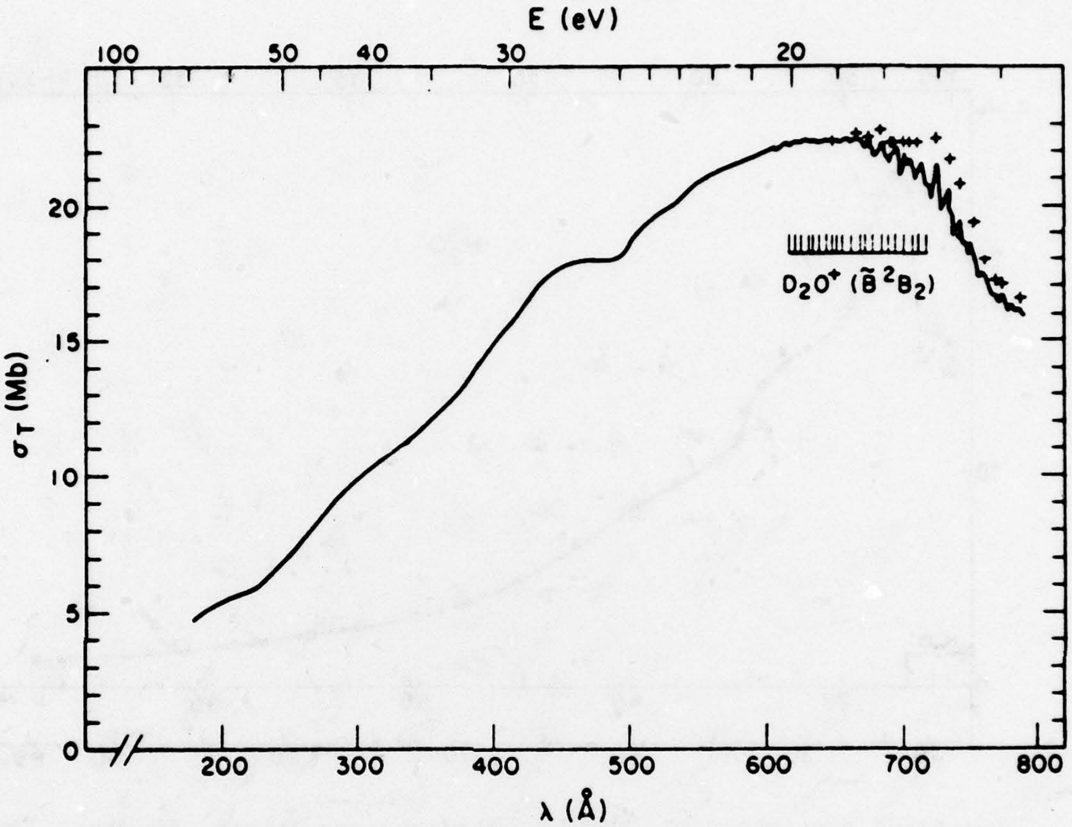
Reference: These data were taken from E. Phillips, L. C. Lee, and D. L. Judge, J. Quant. Spectrosc. Radiat. Transfer 18, 309 (1977).



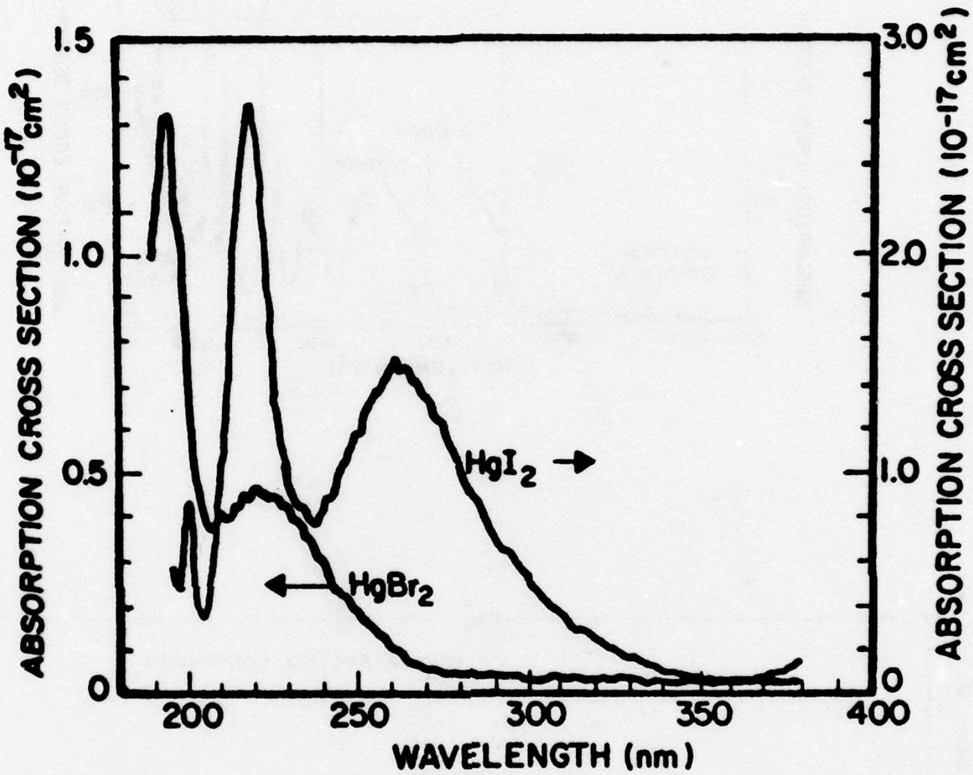
Graphical Data D-2.C-11. Photoabsorption cross sections for H_2O and D_2O in the threshold region. These data were taken from E. Phillips, L. C. Lee, and D. L. Judge, J. Quant. Spectrosc. Radiat. Transfer 18, 309 (1977).



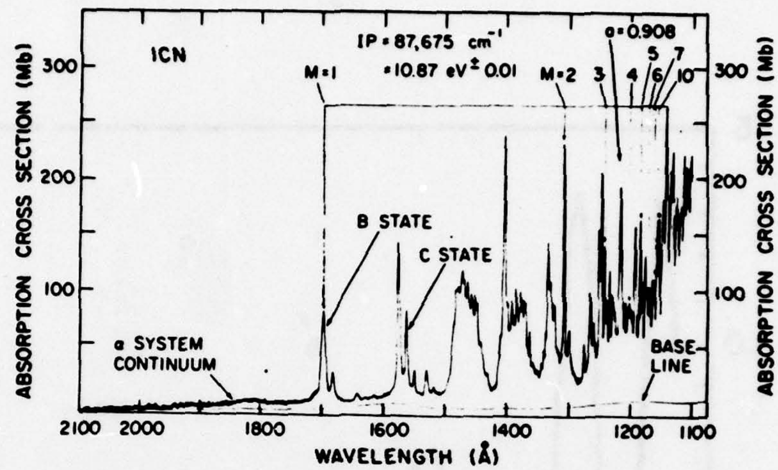
Graphical Data D-2.C-12 Photoabsorption cross section for H_2O. This figure was taken from L. de Reilhac and N. Damany, J. Quant. Spectrosc. Radiat. Transfer 18, 121 (1977). The data are from: ● - above paper; ○ - N. Wainfan, W. C. Walker, and G. L. Weissler, Phys. Rev. 99, 542 (1955).

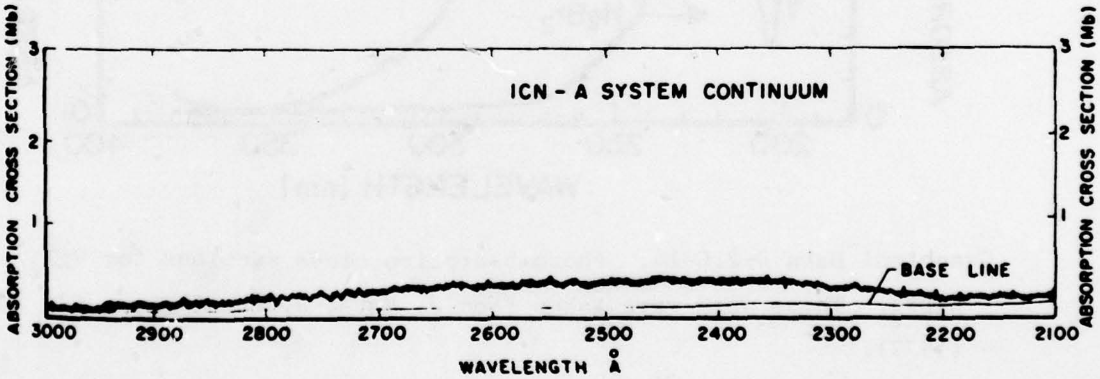


Graphical Data D-2.C-13. Photoabsorption cross section for D_2O. This figure was taken from E. Phillips, L. C. Lee, and D. L. Judge, J. Quant. Spectrosc. Radiat. Transfer 18, 309 (1977). The solid line is data from that paper while the + are from D. H. Katayama, R. E. Huffman, and C. L. O'Bryan, J. Chem. Phys. 59, 4309 (1973).

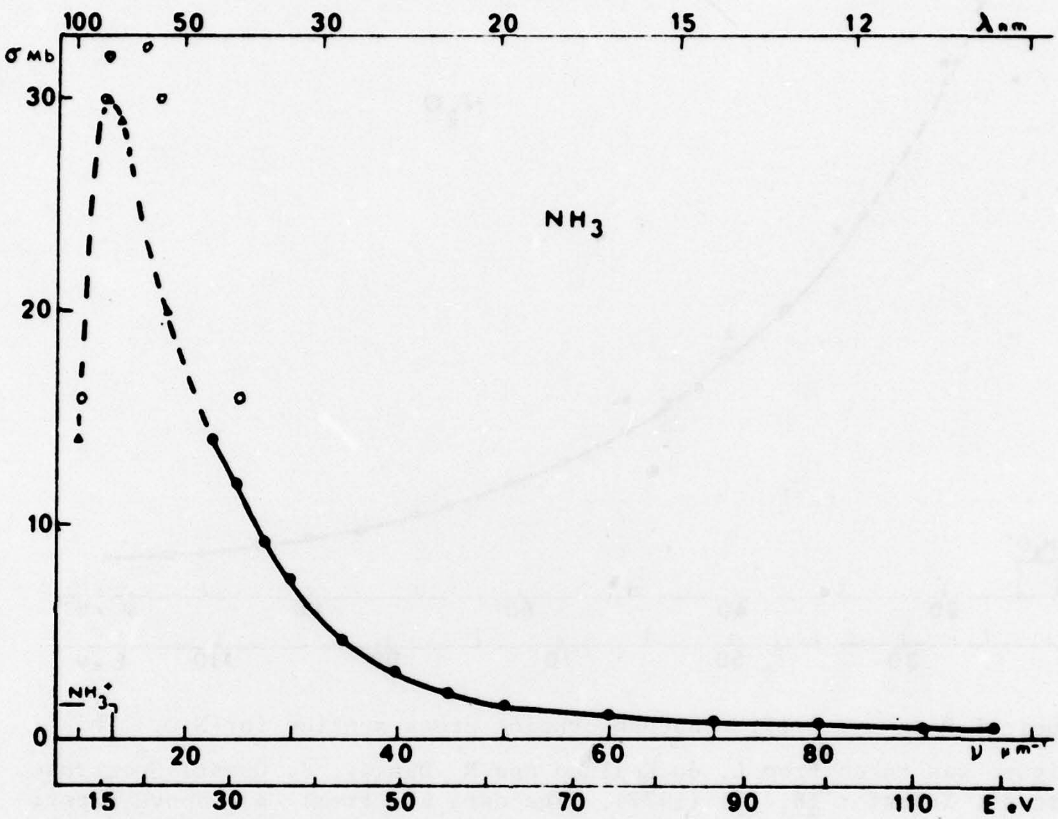


Graphical Data D-2.C-14. Photoabsorption cross sections for HgI_2 and $HgBr_2$. These data were taken from J. Maya, J. Chem. Phys. 67, 4976 (1977).

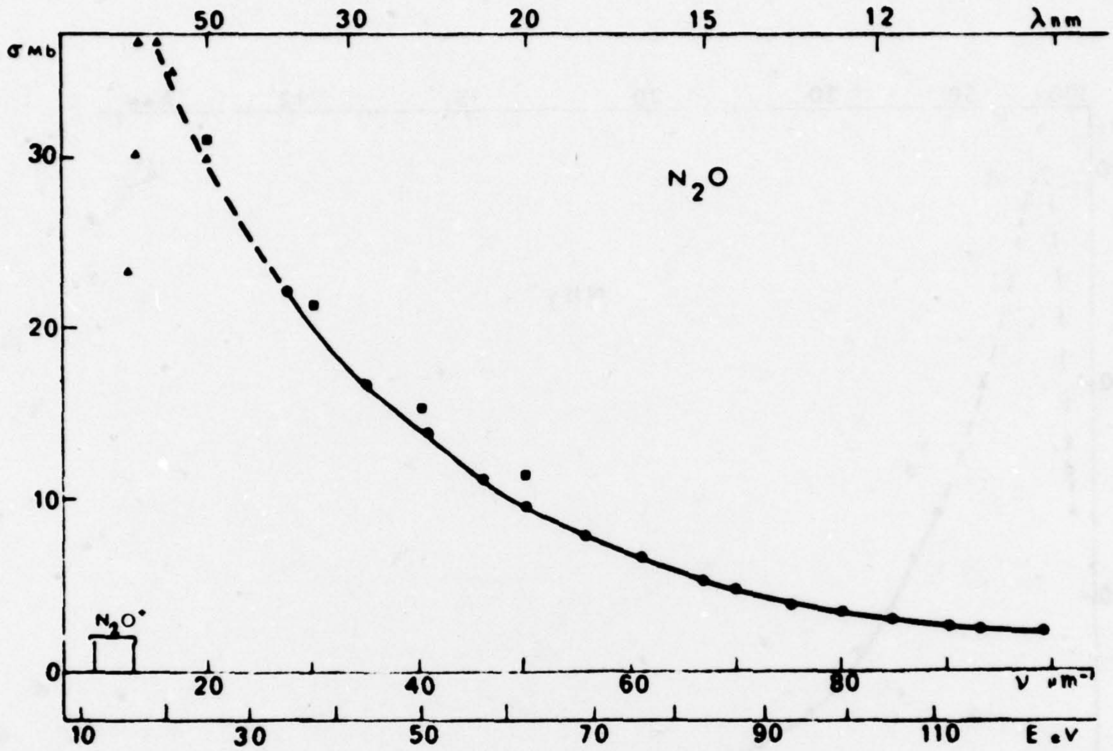




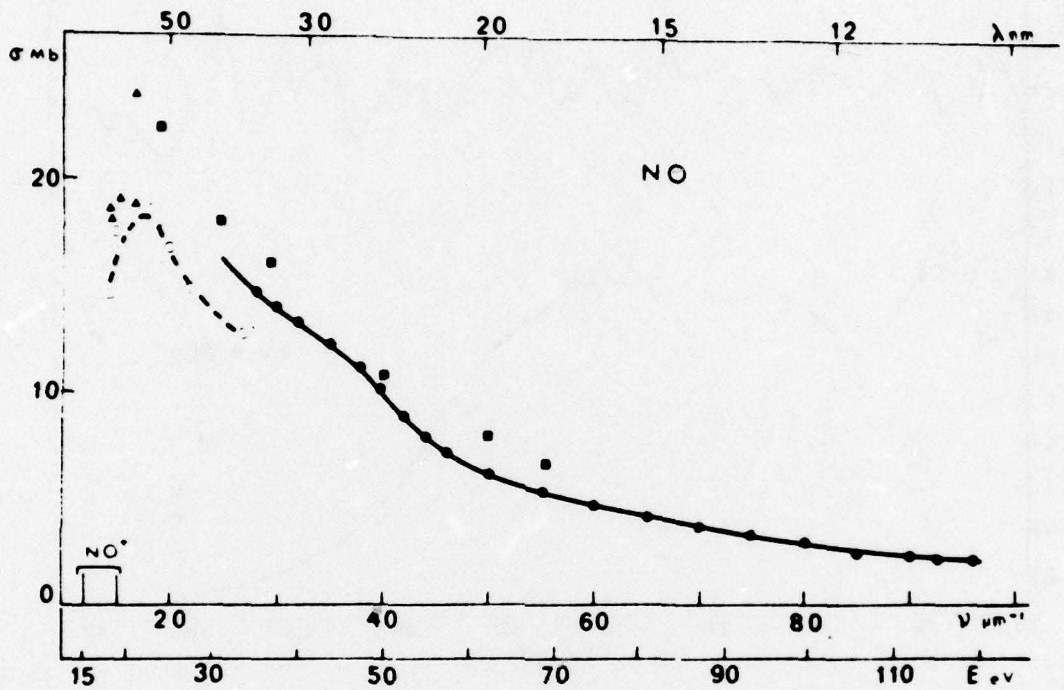
Graphical Data D-2.C-15. Photoabsorption cross section of ICN. These data were taken from J. A. Myer and J. A. R. Samson, J. Chem. Phys. 52, 266 (1970).



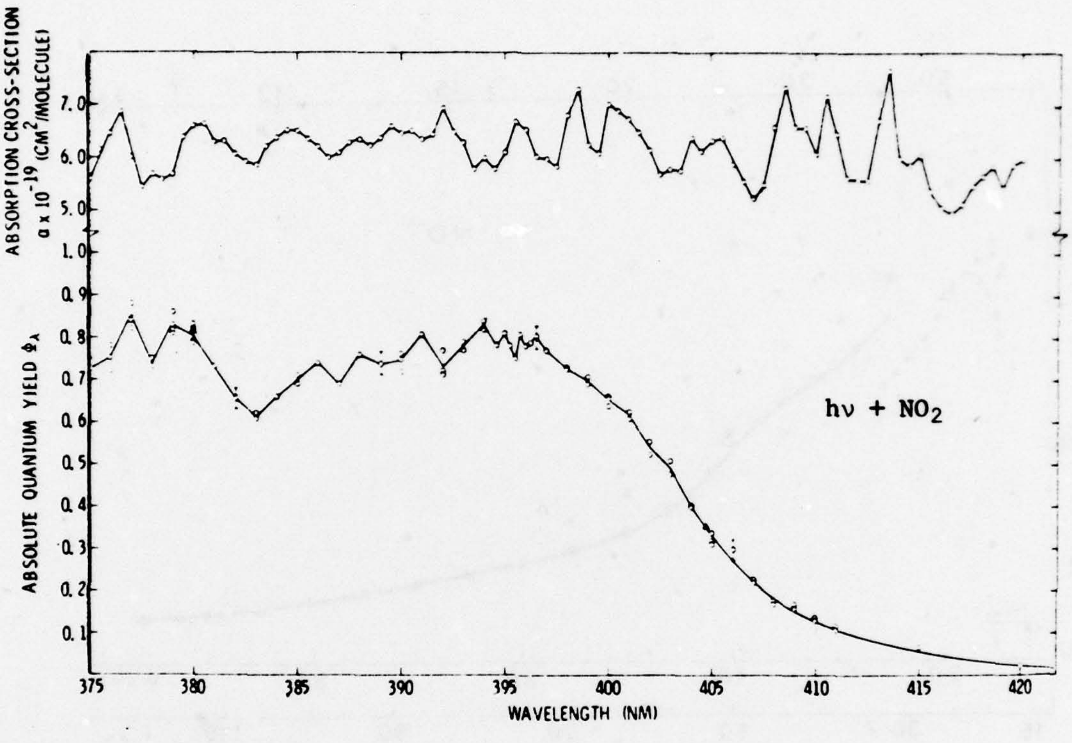
Graphical Data D-2.C-16. Photoabsorption cross section for NH_3. This figure was taken from L. de Reilhac and N. Damany, J. Quant. Spectrosc. Radiat. Transfer 18, 121 (1977). The data are from: ● - above paper; ⊙ - W. C. Walker and G. L. Weissler, J. Chem. Phys. 23, 1540 (1955); ▲ - P. H. Metzger and G. R. Cook, J. Chem. Phys. 41, 642 (1964).



Graphical Data D-2.C-17. Photoabsorption cross section for N_2O. This figure was taken from L. de Reilhac and N. Damany, J. Quant. Spectrosc. Radiat. Transfer 18, 121 (1977). The data are from: ● - above paper; ▲ - G. R. Cook, P. H. Metzger, and M. Ogawa, J. Opt. Soc. Am. 58, 129 (1968); ■ - L. C. Lee, R. W. Carlson, D. L. Judge, and M. Ogawa, J. Quant. Spectrosc. Radiat. Transfer 13, 1023 (1973).



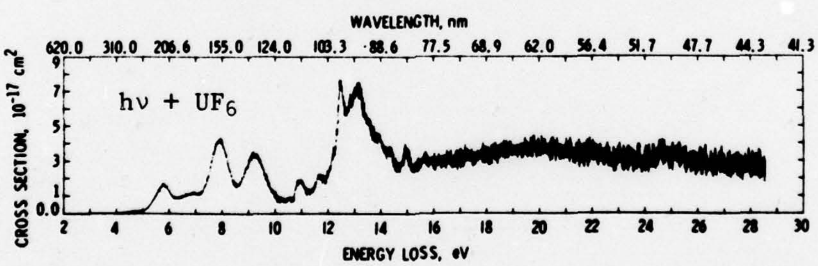
Graphical Data D-2.C-18. Photoabsorption cross section for NO. This figure was taken from L. de Reilhac and N. Damany, J. Quant. Spectrosc. Radiat. Transfer 18, 121 (1977). The data are from: ● - above paper; o - H. Sun and G. L. Weissler, J. Chem. Phys. 23, 1372 (1955); ▲ - P. H. Metzger, G. R. Cook, and M. Ogawa, Can. J. Phys. 45, 203 (1967); ■ - L. C. Lee, R. W. Carlson, D. L. Judge, and M. Ogawa, J. Quant. Spectrosc. Radiat. Transfer 13, 1023 (1973).



Graphical Data D-2.C-19 Photoabsorption cross section and quantum yield for NO_2. These data were taken from A. B. Harker, W. Ho, and J. J. Ratto, Chem. Phys. Letts. 50, 394 (1977).

Tabular and Graphical Data D-2.C-20. Photoabsorption cross section for UF_6 (units of 10^{-17} cm^2).

E(eV)	λ(nm)	σ	E(eV)	λ(nm)	σ
4.0	310.0	0.014	16.5	75.2	3.06
4.5	275.5	0.086	17.0	72.9	3.26
5.0	248.0	0.15	17.5	70.8	3.34
5.5	225.5	1.15	18.0	68.9	3.34
6.0	206.6	1.27	18.5	67.0	3.64
6.5	190.8	0.99	19.0	65.3	3.76
7.0	177.1	1.15	19.5	63.6	3.76
7.5	165.3	2.49	20.0	62.0	3.83
8.0	155.0	4.03	20.5	60.5	3.76
8.5	145.9	1.65	21.0	59.0	3.64
9.0	137.8	3.11	21.5	57.7	3.64
9.5	130.5	2.72	22.0	56.4	3.45
10.0	124.0	0.92	22.5	55.1	3.26
10.5	118.1	0.88	23.0	53.9	3.37
11.0	112.7	1.76	23.5	52.8	3.14
11.5	107.8	1.57	24.0	51.7	3.07
12.0	103.3	2.30	24.5	50.6	3.45
12.5	99.2	7.66	25.0	49.6	3.45
13.0	95.4	7.17	25.5	48.6	3.26
13.5	91.9	5.29	26.0	47.7	3.26
14.0	88.6	4.22	26.5	46.8	2.88
14.5	85.5	2.99	27.0	45.9	2.88
15.0	82.7	3.41	27.5	45.1	2.88
15.5	80.0	2.87	28.0	44.3	2.79
16.0	77.5	2.99	28.5	43.5	2.68



Note: The relative accuracy in these measurements is ±20%; the absolute accuracy is ±27%.

Reference: These data were taken from S. K. Srivastava, D. C. Cartright, S. Trajmar, A. Chutjian, and W. X. Williams, J. Chem. Phys. 65, 208 (1976).

Comments: The units of cm^2/eV for photoabsorption given in the original paper are not correct; the figures and table should read $\sigma(cm^2)$ rather than $d\sigma/dE(cm^2/eV)$.

Section D-2.D. RELATIVE PHOTOABSORPTION, PHOTOIONIZATION, AND PHOTODISSOCIATION CROSS SECTIONS FOR BrCN, CH_3Br, CH_3Cl, CH_3F, C_2N_2, ClCN, ClF, F_2, FCN, F_2O, HCl, HF, ICN, and NO_2

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D-2.D-16. Relative Photoionization Cross Section for NO_2 2028

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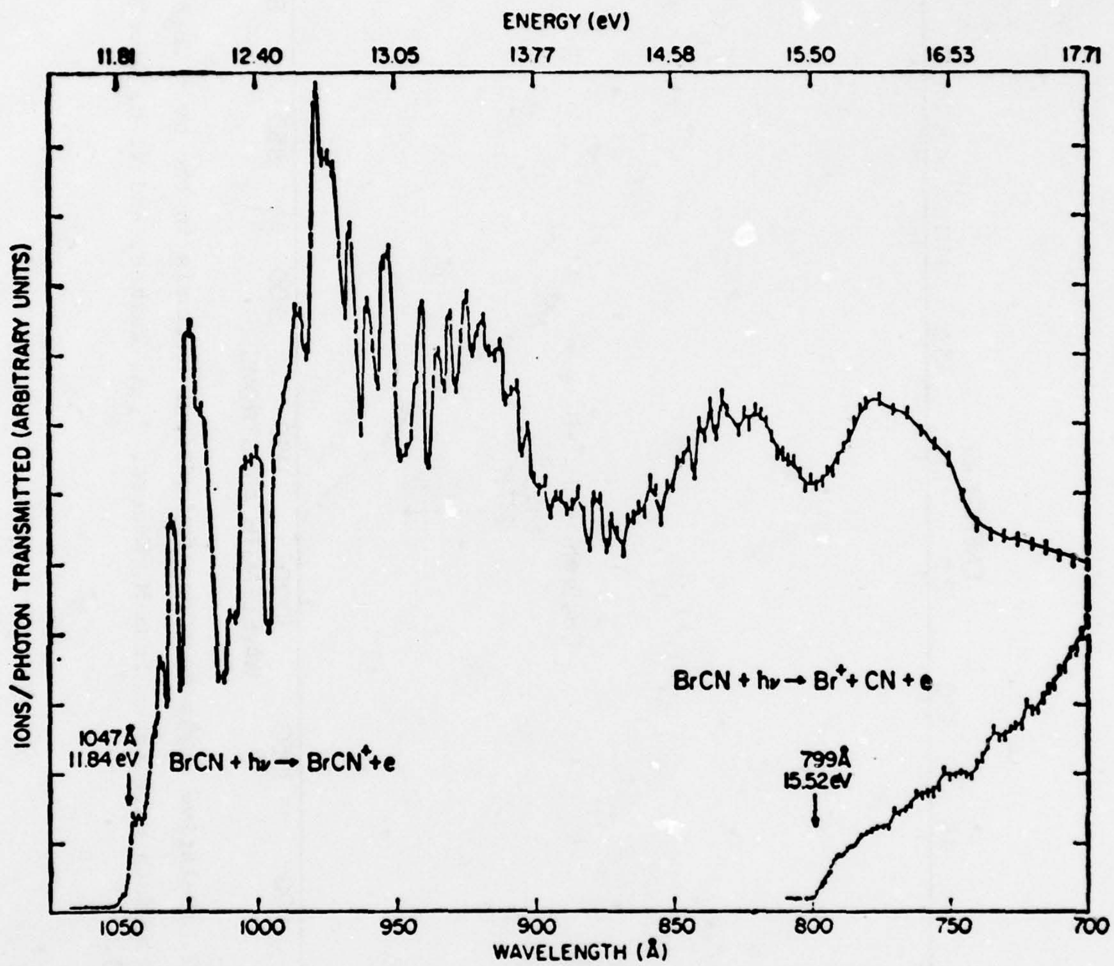
D-2.D-18. Relative Cross Sections for Various Channels in the hν + NO_2 Photoionization Process 2030



Graphical Data D-2.D-1. Relative cross sections for various channels in the hν + BrCN photoionization process. These data were taken from V. H. Dibeler and S. K. Liston, J. Chem. Phys. 47, 4548 (1967).

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COMPILATION OF DATA RELEVANT TO NUCLEAR PUMPED LASERS. VOLUME V--ETC(U)
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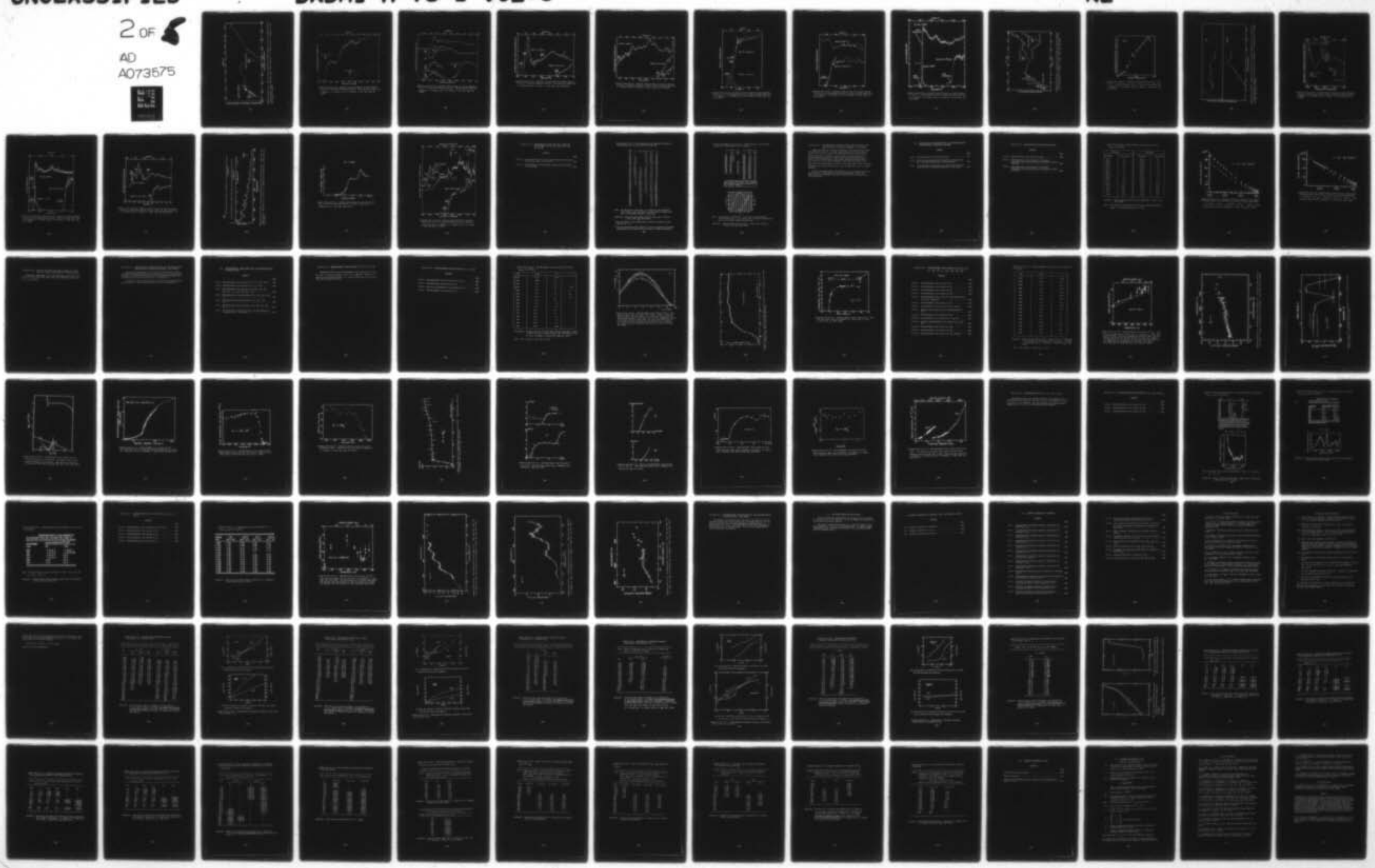

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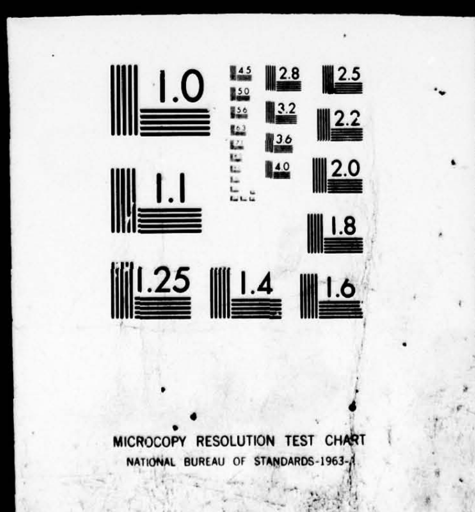
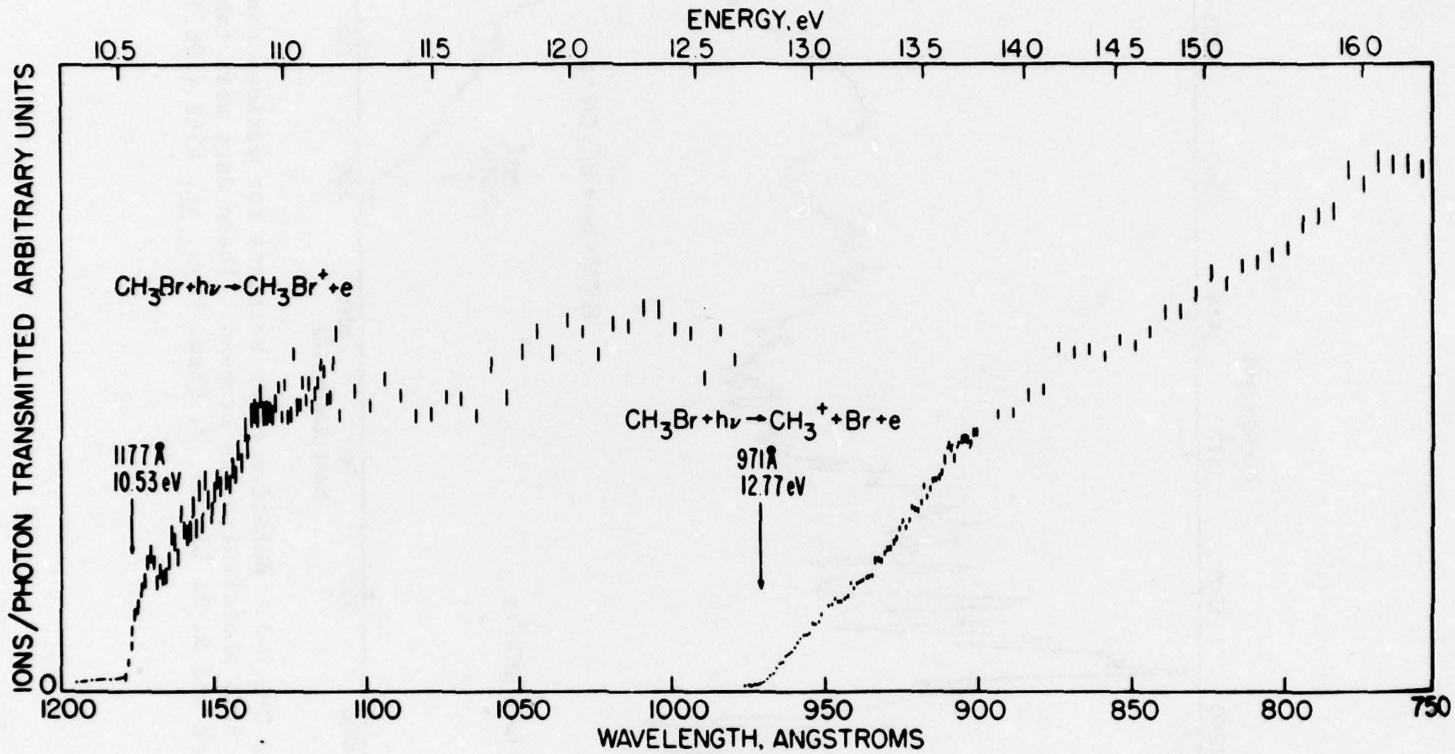
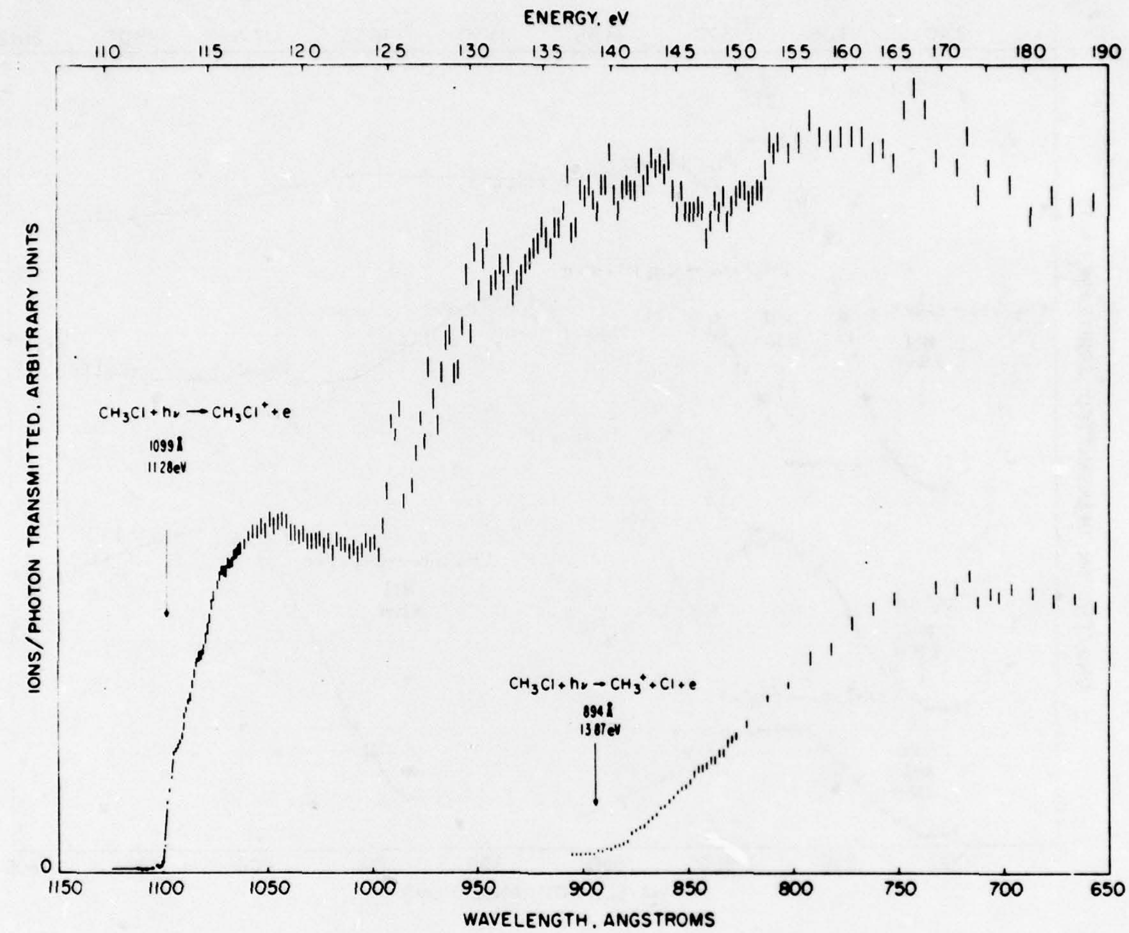
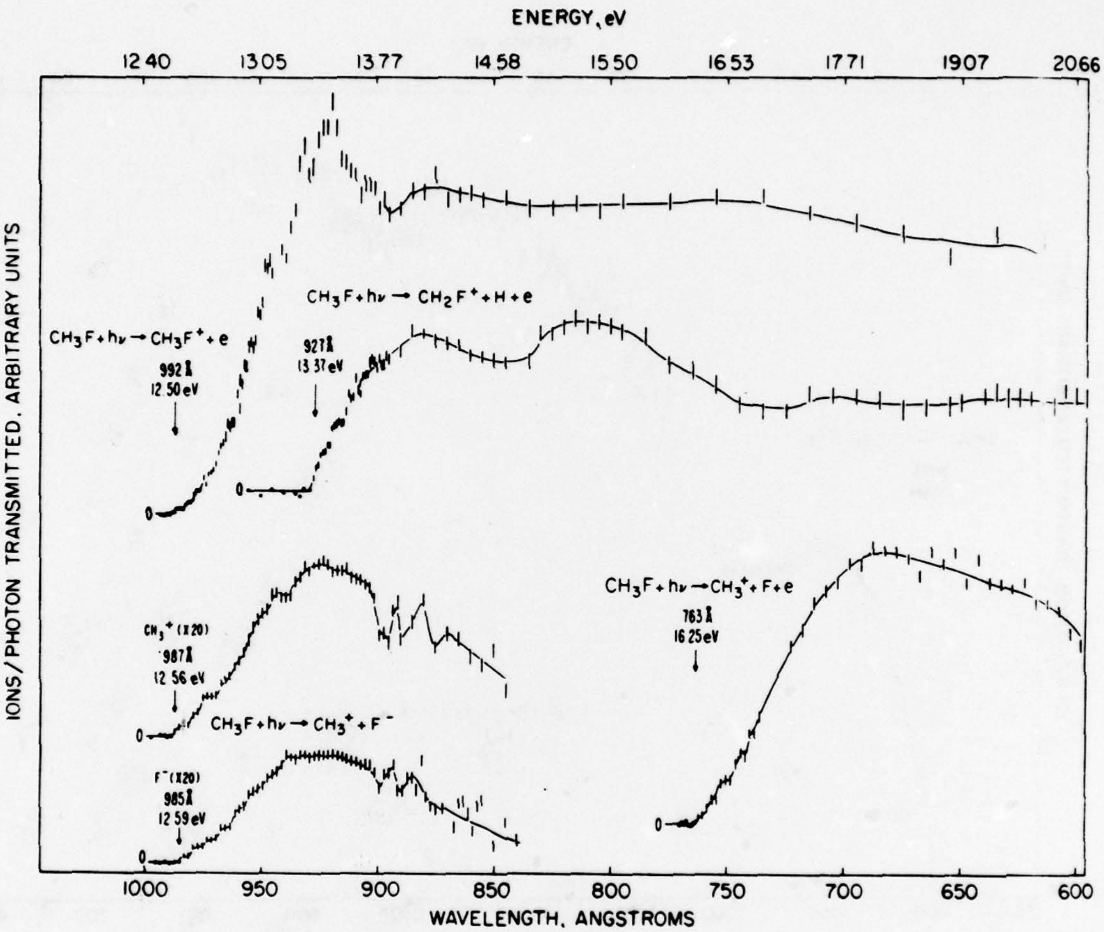




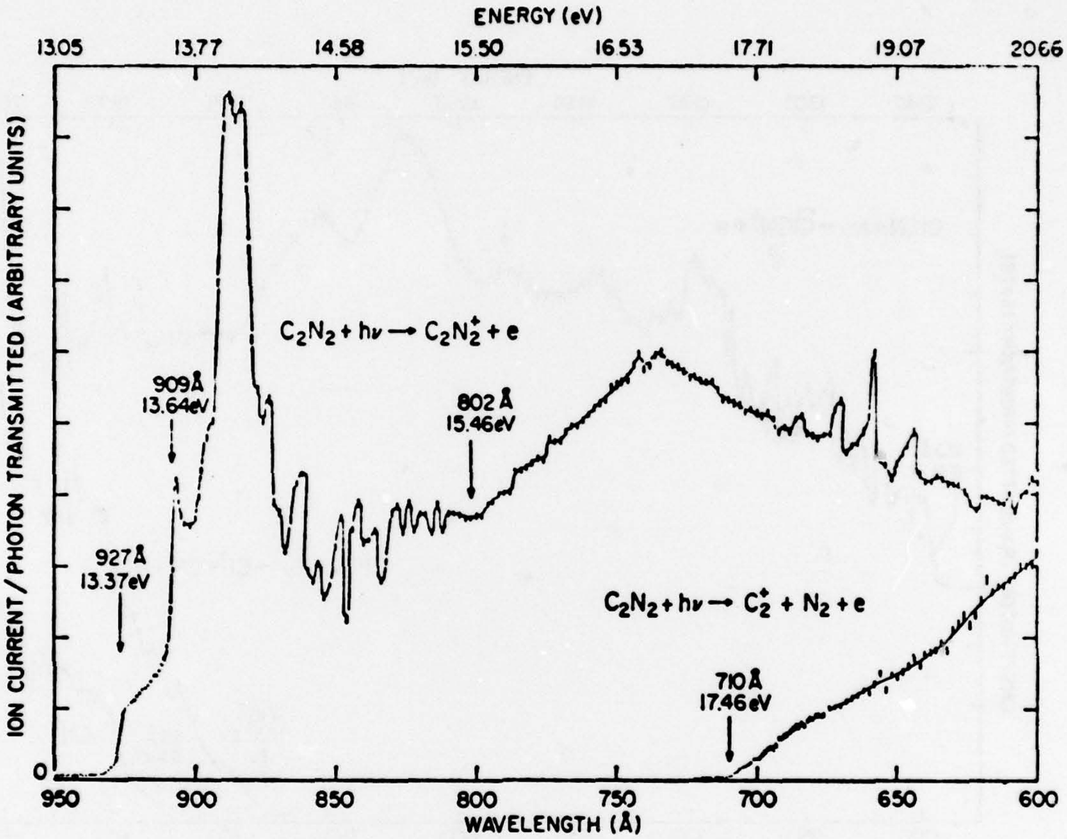
Graphical Data D-2.D-2. Relative cross sections for various channels in the $h\nu + CH_3Br$ photoionization process. These data were taken from M. Krauss, J. A. Walker, and V. H. Dibeler, J. Res. NBS, 72A, 281 (1968).



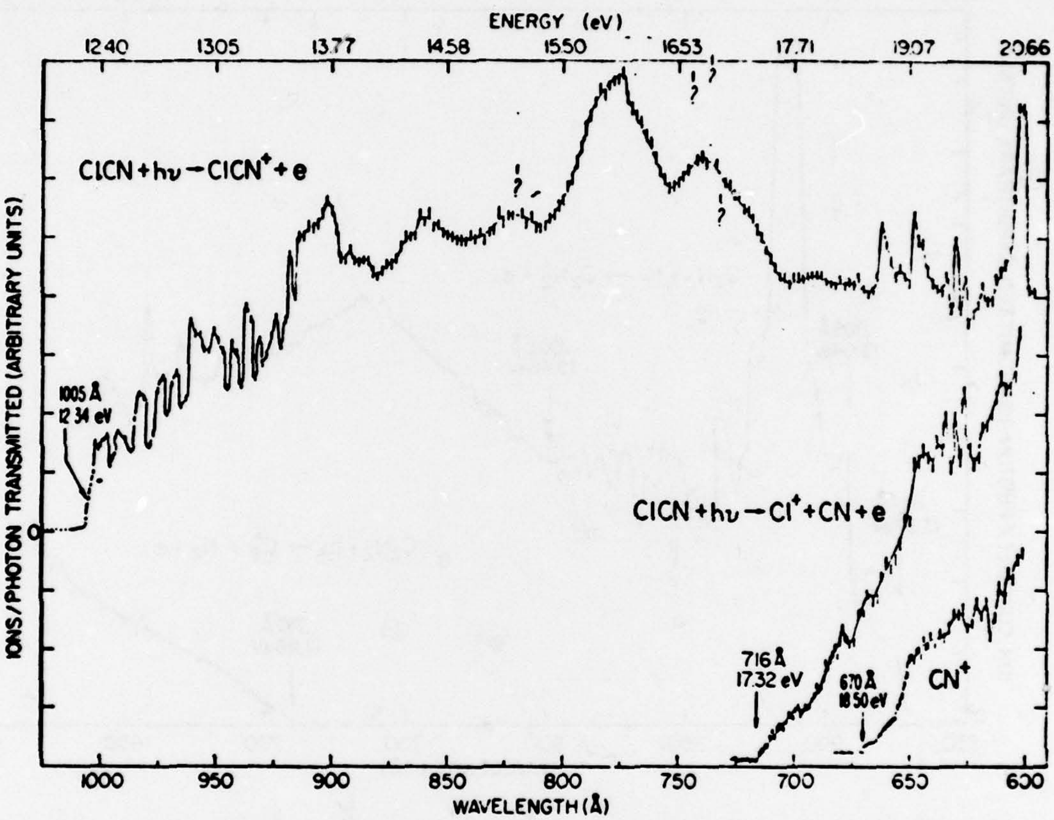
Graphical Data D-2.D-3. Relative cross sections for various channels in the $h\nu + CH_3Cl$ photoionization process. These data were taken from M. Krauss, J. A. Walker, and V. H. Dibeler, J. Res. NBS, 72A, 281 (1968).



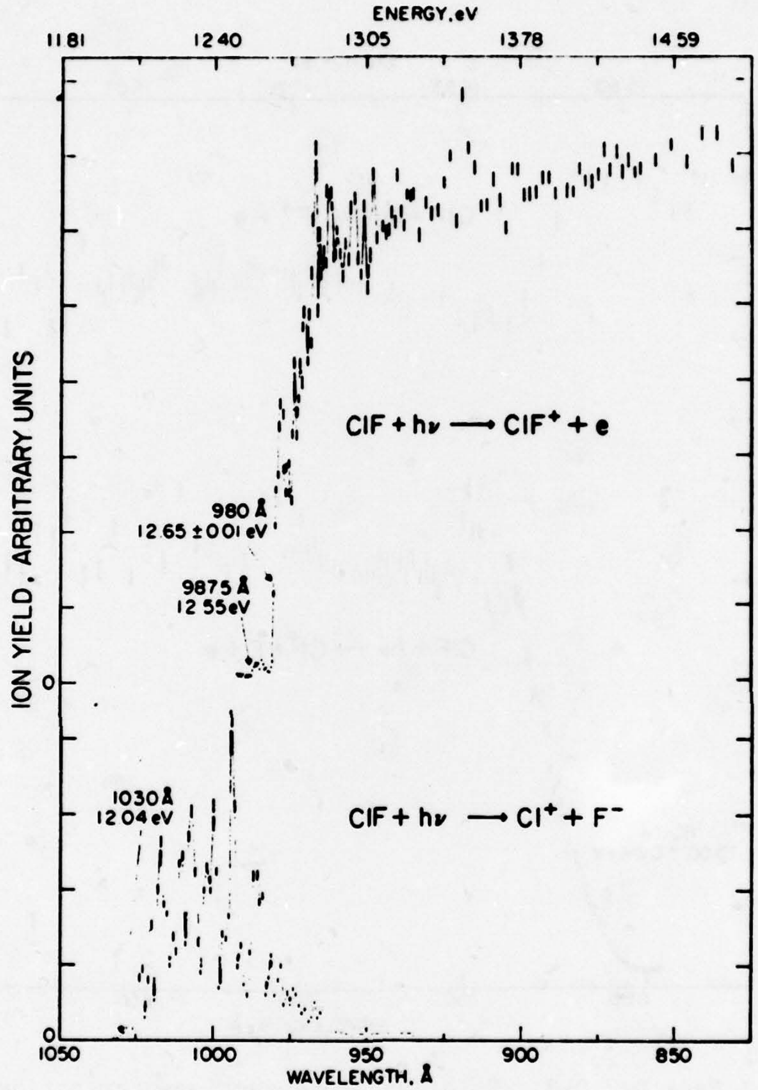
Graphical Data D-2.D-4. Relative cross sections for various channels in the hν + CH_3F photoionization process. These data were taken from M. Krauss, J. A. Walker, and V. H. Dibeler, J. Res. NBS, 72A, 281 (1968).



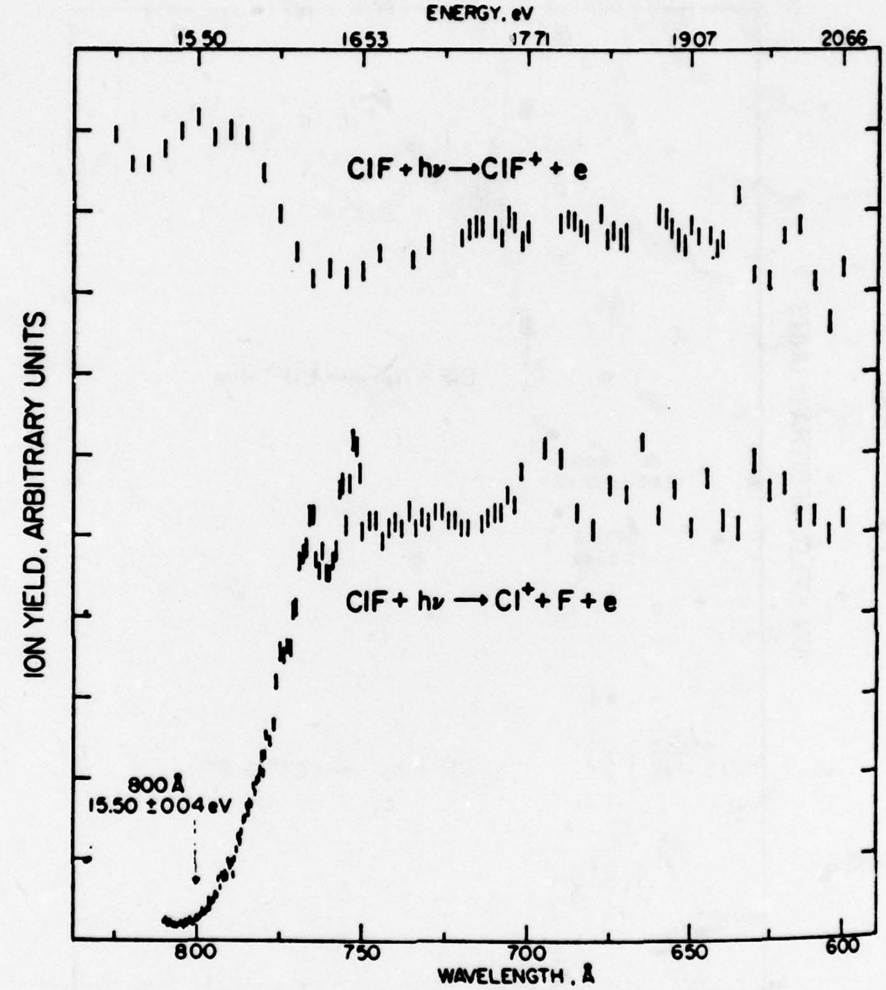
Graphical Data D-2.D-5. Relative cross sections for various channels in the $h\nu + C_2N_2$ photoionization process. These data were taken from V. H. Dibeler and S. K. Liston, J. Chem. Phys. 47, 4548 (1967).



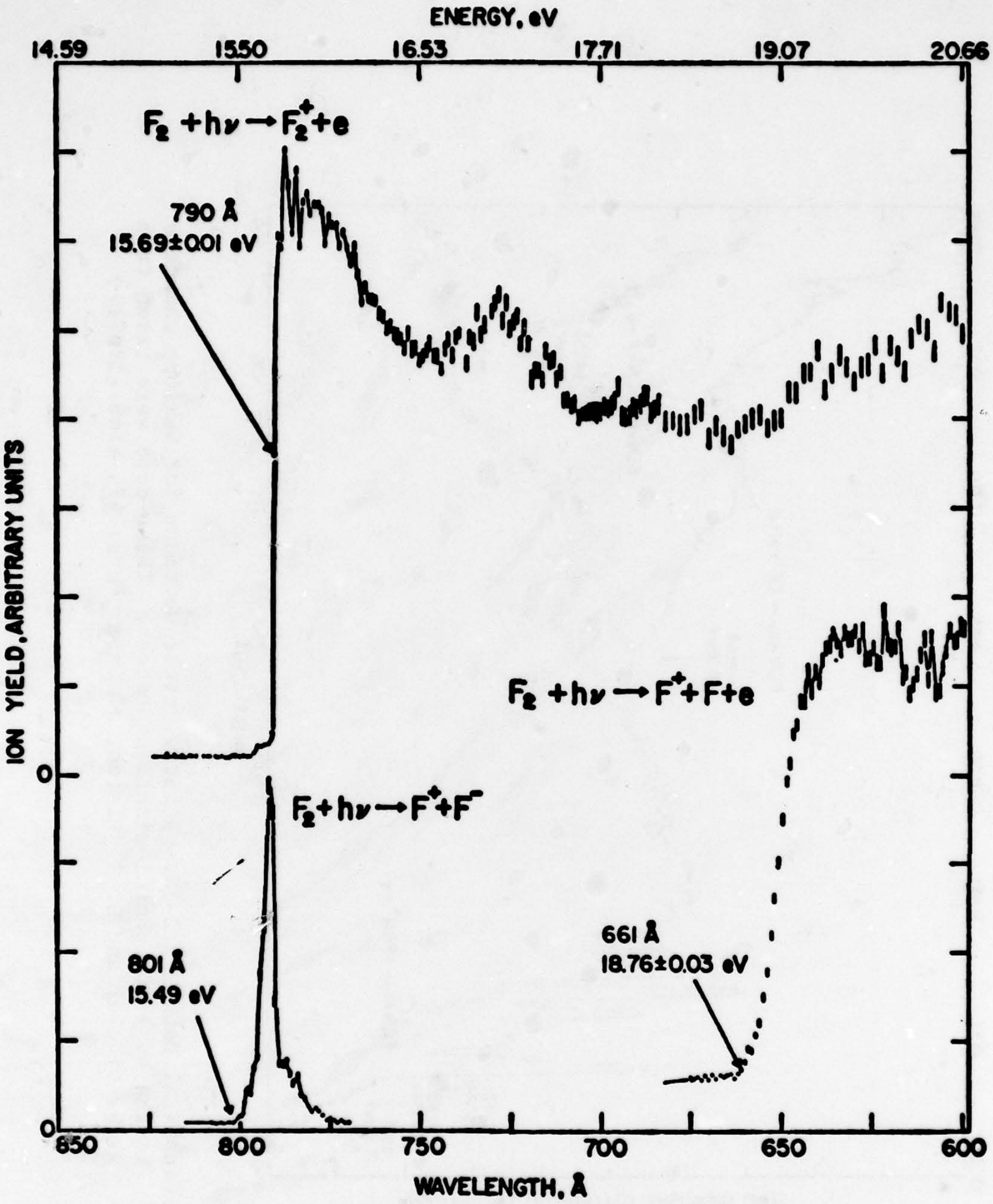
Graphical Data D-2.D-6. Relative cross sections for various channels in the hν + ClCN photoionization process. These data were taken from V. H. Dibeler and S. K. Liston, J. Chem. Phys. 47, 4548 (1967).



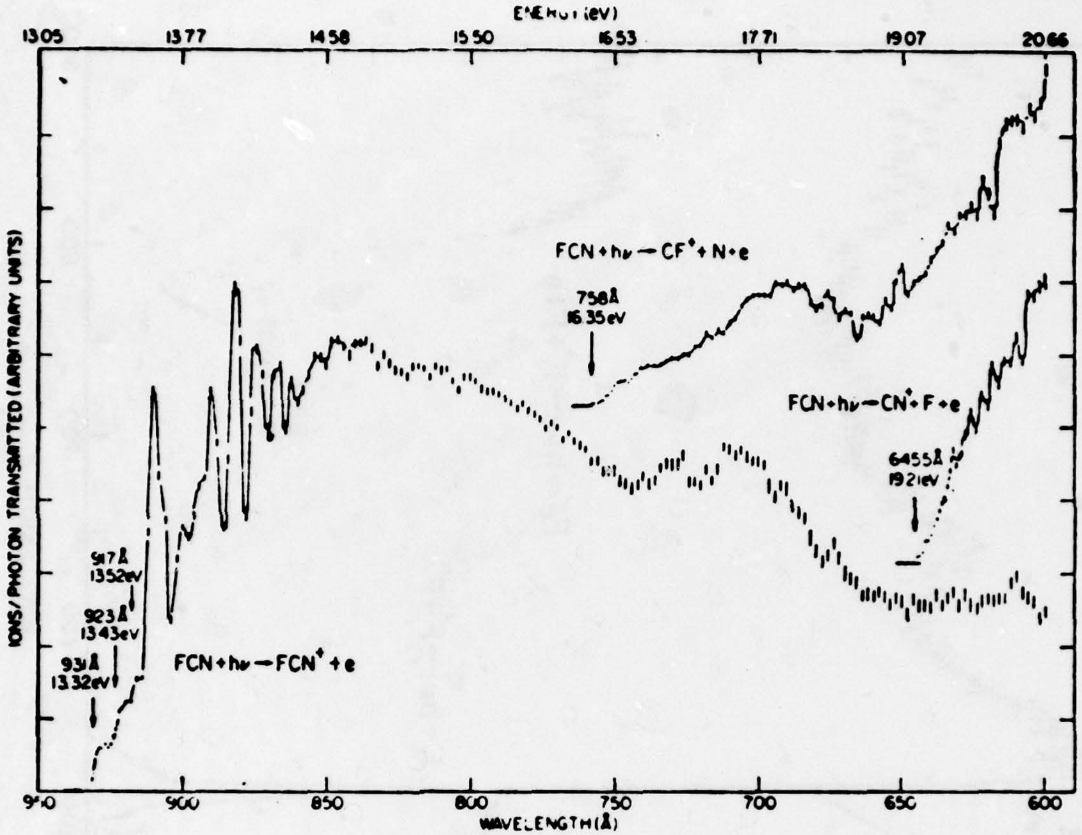
Graphical Data D-2.D-7. Relative cross sections for various channels of the hν + ClF photoabsorption process. These data were taken from V. H. Dibeler, J. A. Walker, and K. E. McCulloh, J. Chem. Phys. 53, 4414 (1970).



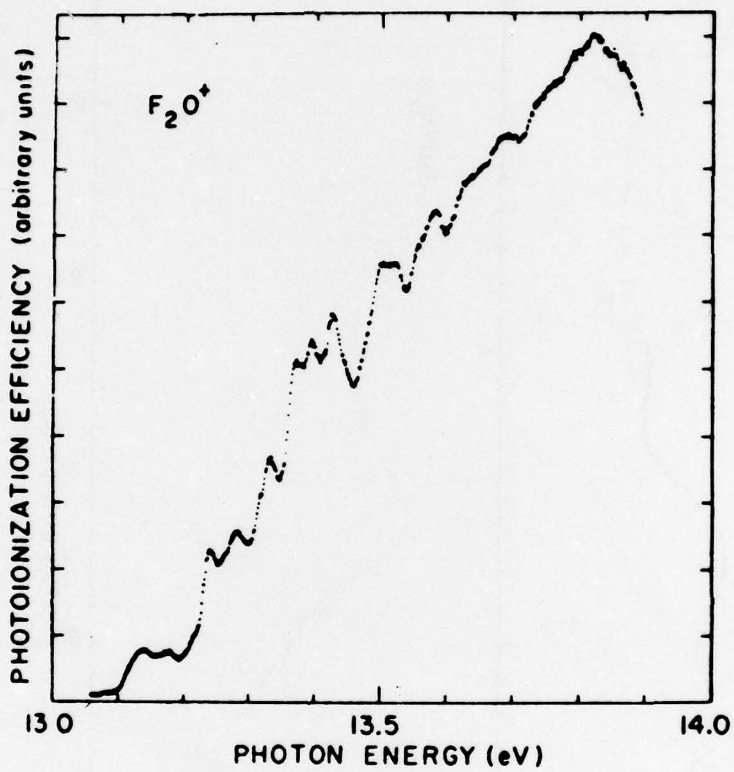
Graphical Data D-2.D-8. Relative cross sections for various channels of the hν + ClF photoabsorption process. These data were taken from V. H. Dibeler, J. A. Walker, and K. E. McCulloh, J. Chem. Phys. 53, 4414 (1970).



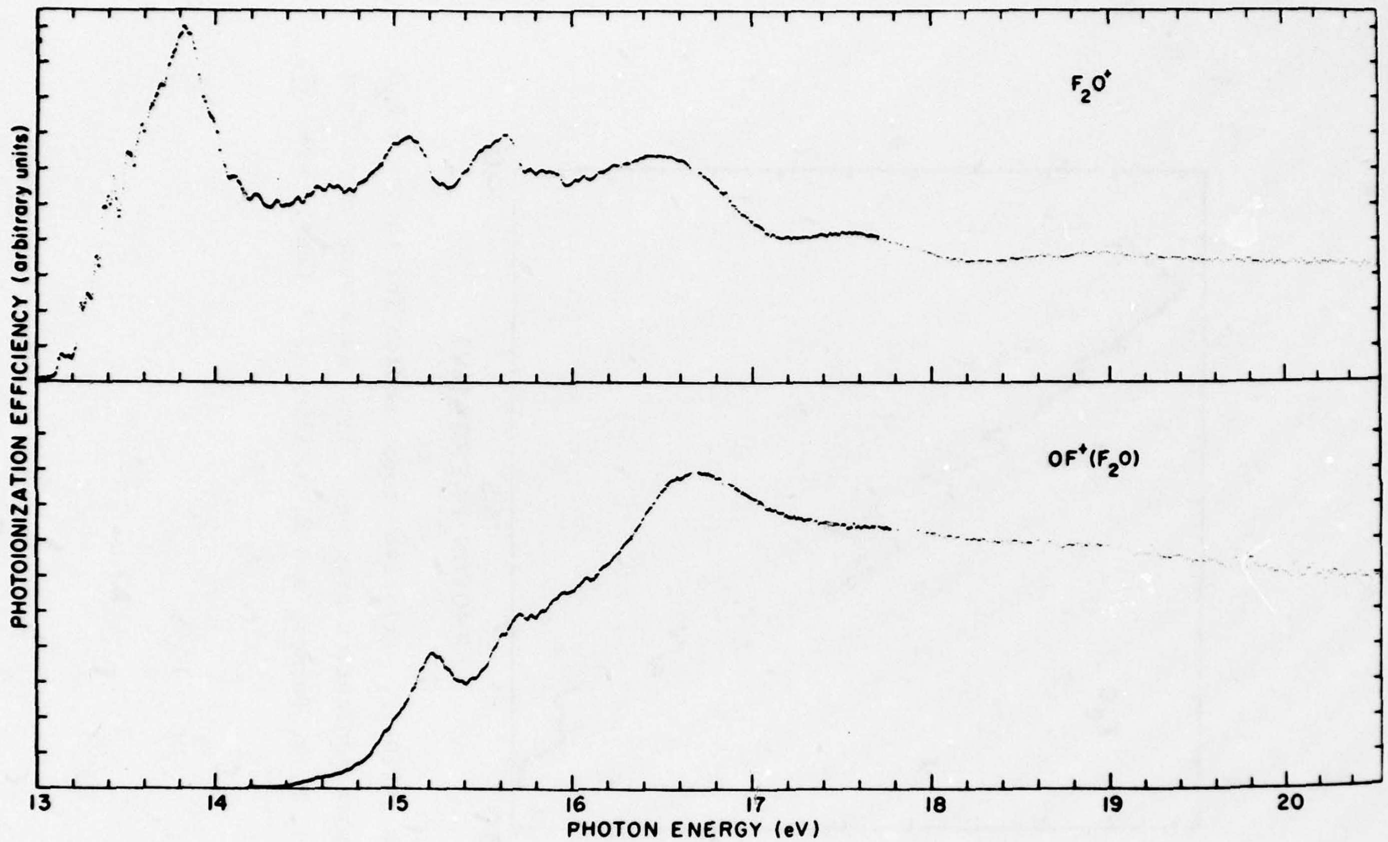
Graphical Data D-2.D-9. Relative cross sections for various channels of the $h\nu + F_2$ photoabsorption process. These data were taken from V. H. Dibeler, J. A. Walker, and K. E. McCulloh, J. Chem. Phys. 50, 4592 (1969).



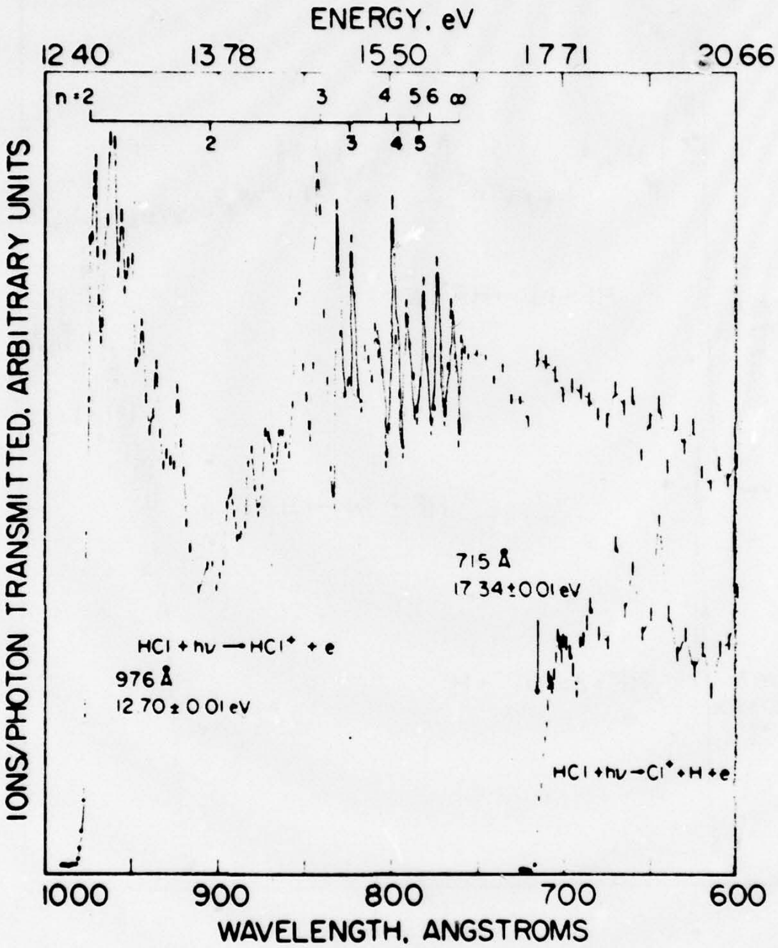
Graphical Data D-2.D-10. Relative cross sections for various channels in the hν + FCN photoionization process. These data were taken from V. H. Dibeler and S. K. Liston, J. Chem. Phys. 47, 4548 (1967).



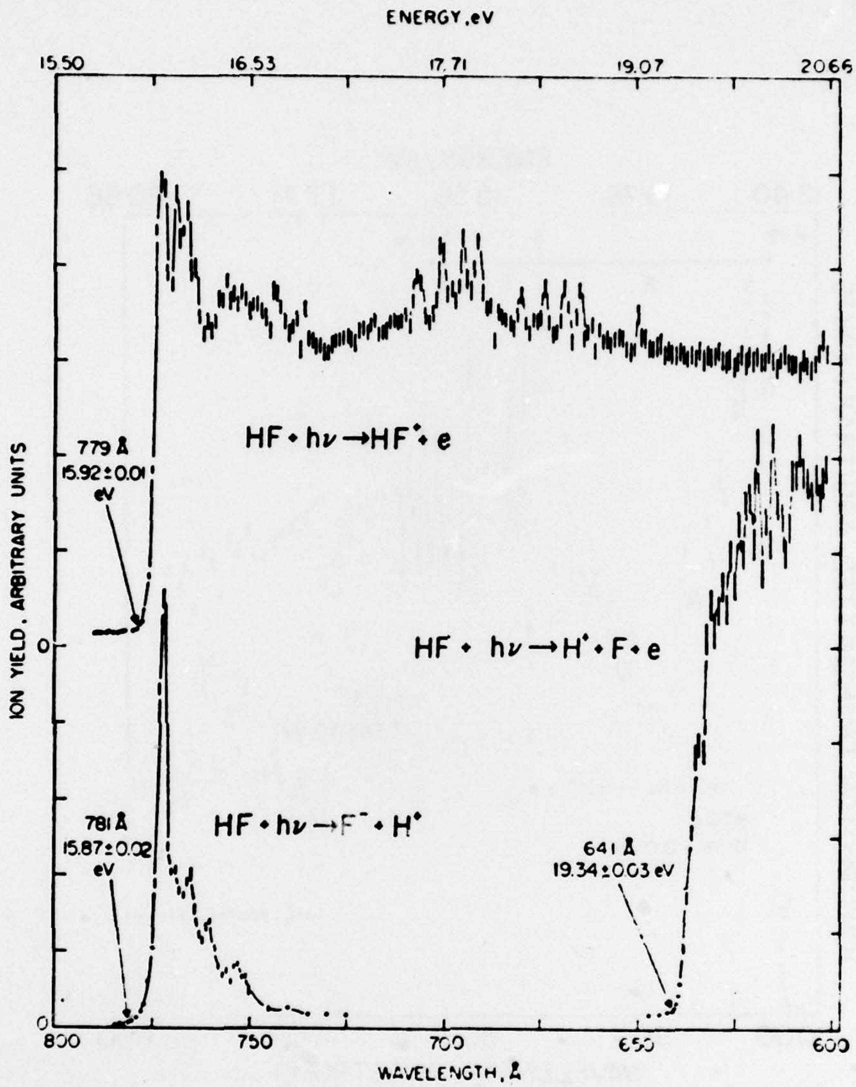
Graphical Data D-2.D-11. Relative cross section for the $h\nu + F_2O \rightarrow F_2O^+ + e$ photoionization process. These data were taken from J. Berkowitz, P. N. Dehmer, and W. A. Chupka, J. Chem. Phys. 59, 925 (1973).



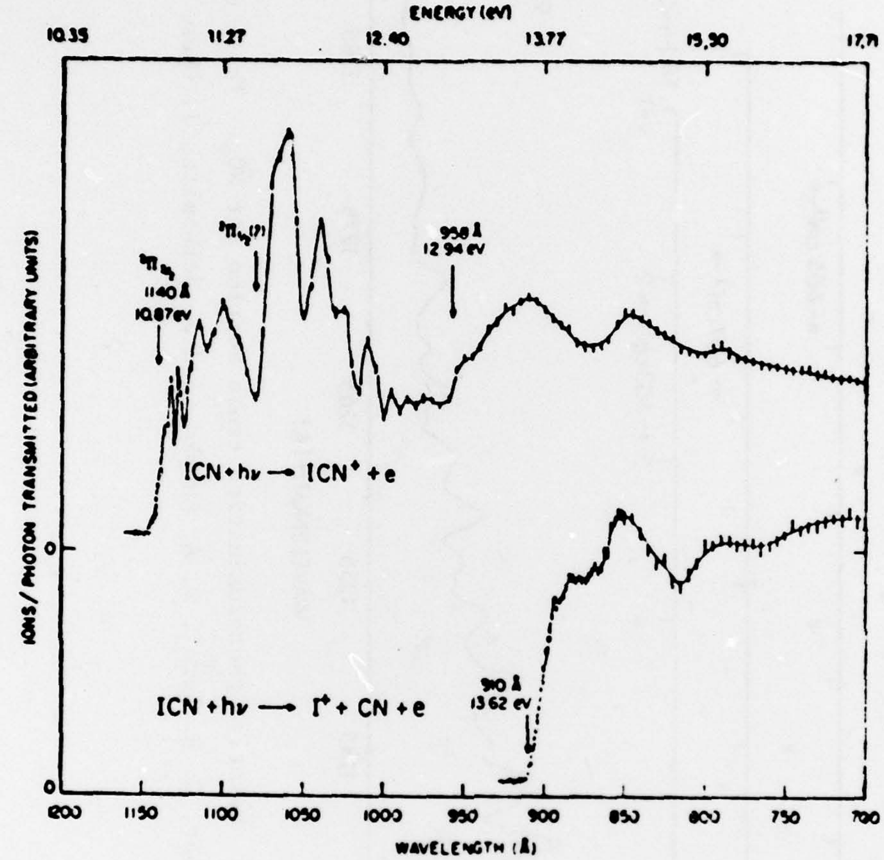
Graphical Data D-2.D-12. Relative cross sections for various channels of the $h\nu + F_2O$ photoionization process. These data were taken from J. Berkowitz, P. M. Dehmer, and W. A. Chupka, J. Chem. Phys. 59, 925 (1973).



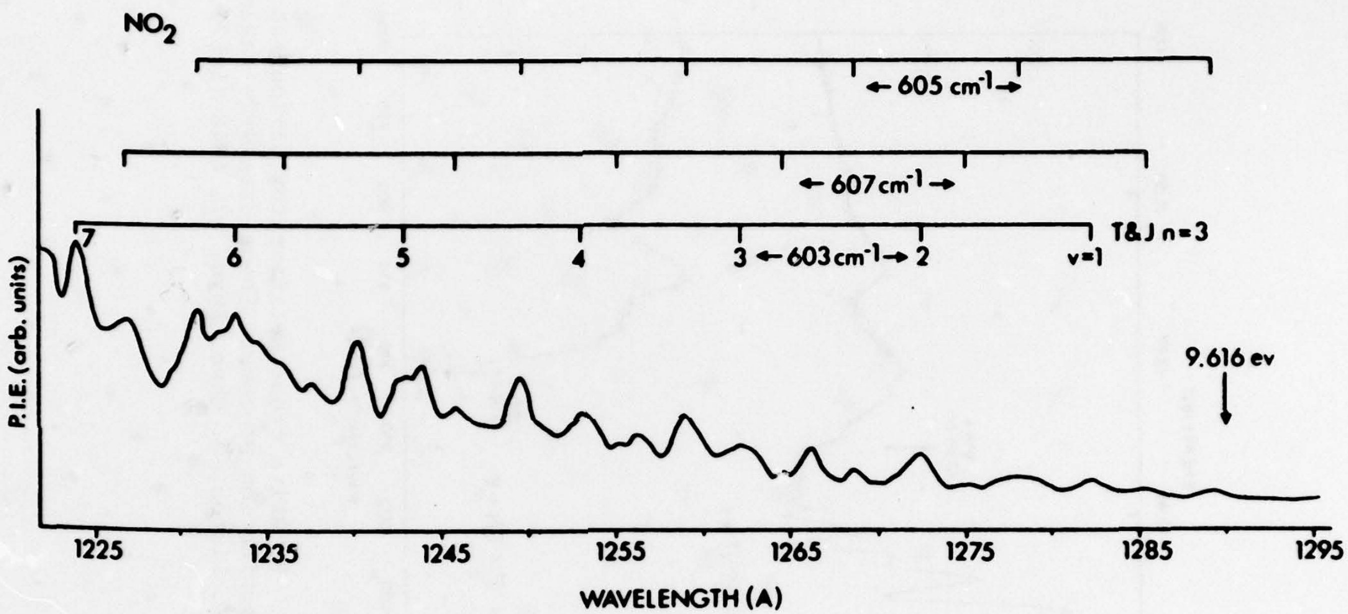
Graphical Data D-2.D-13. Relative cross sections for various channels in the hν + HCl photoionization process. These data were taken from M. Krauss, J. A. Walker, and V. H. Dibeler, J. Res. NBS, 72A, 281 (1968).



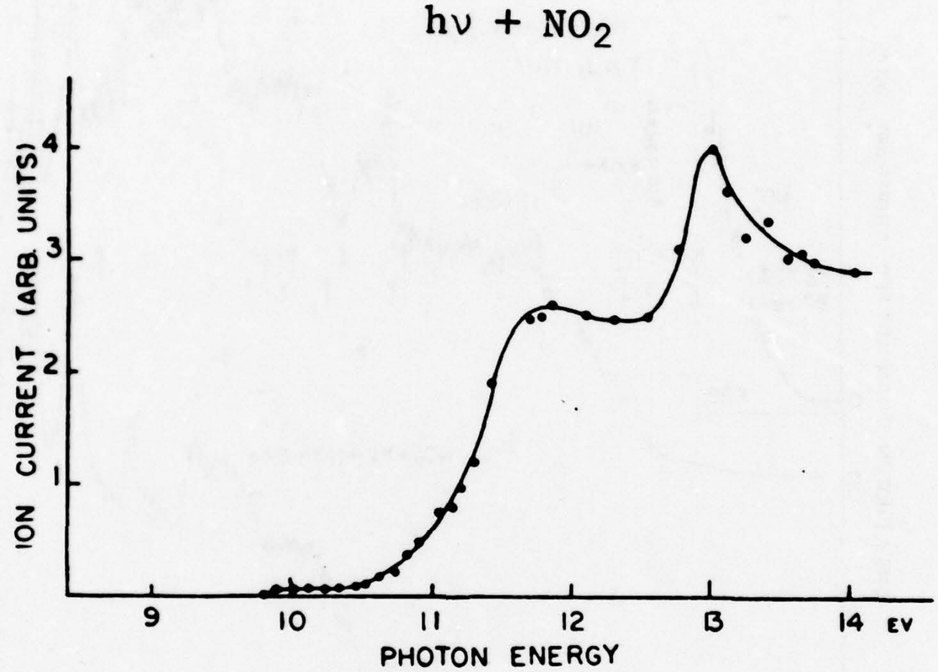
Graphical Data D-2.D-14. Relative cross sections for various channels in the hν + HF photoabsorption process. These data were taken from V. H. Dibeler, J. A. Walker, and K. E. McCulloh, J. Chem. Phys. 51, 4230 (1969).



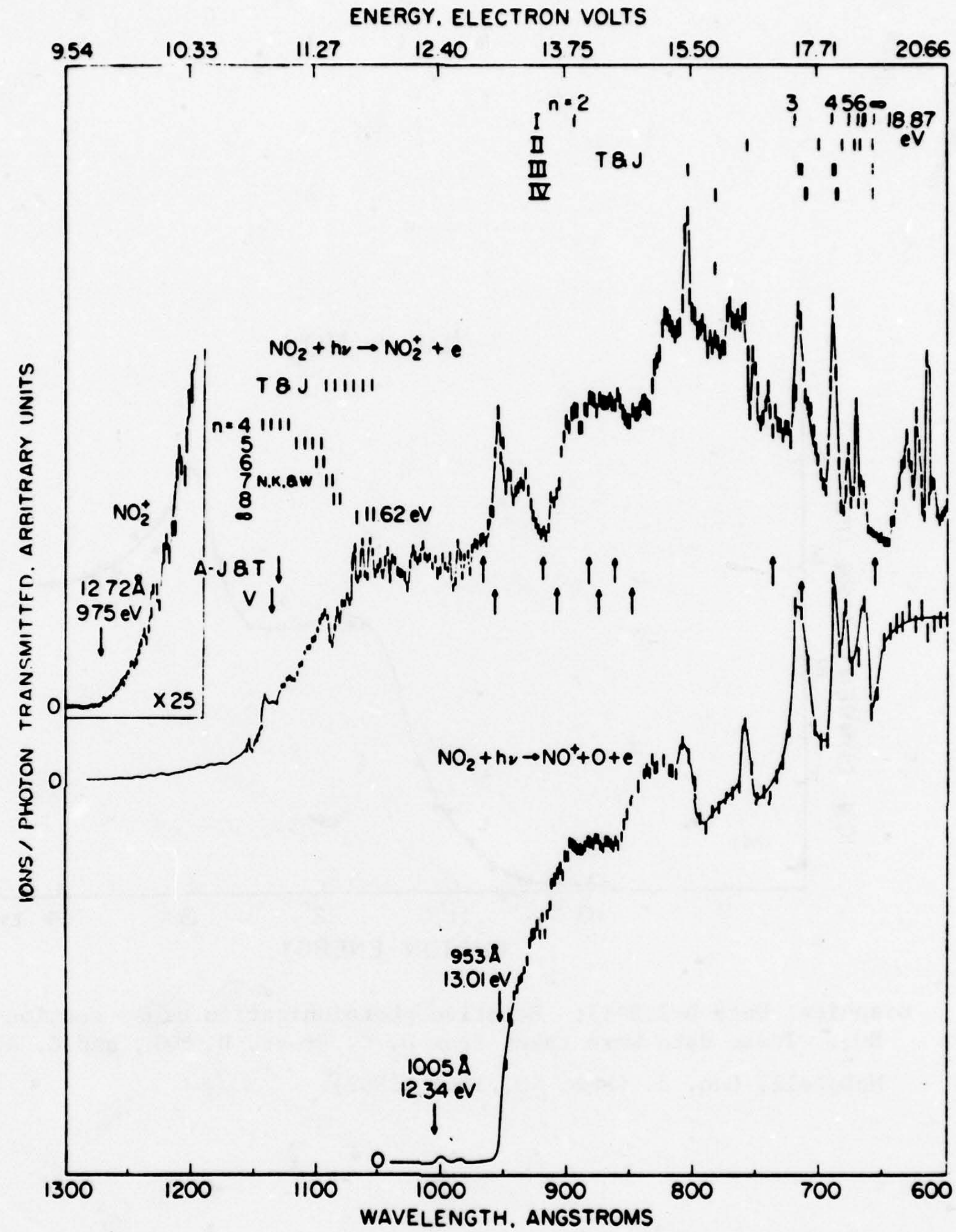
Graphical Data D-2.D-15. Relative cross sections for various channels in the hν + ICN photoionization process. These data were taken from V. H. Dibeler and S. K. Liston, J. Chem. Phys. 47, 4548 (1967).



Graphical Data D-2.D-16. Relative photoionization cross section for NO_2. These data were taken from P.C. Killgoar, G. E. Leroi, W. A. Chupka, and J. Berkowitz, J. Chem. Phys. 59, 1370 (1973).



Graphical Data D-2.D-17. Relative photoionization cross section for NO_2. These data were taken from D. C. Frost, D. Mak, and C. A. McDowell, Can. J. Chem. 40, 1064 (1962).



Graphical Data D-2.D-18. Relative cross sections for various channels in the hν + NO_2 photoionization process. These data were taken from V. H. Dibeler, J. A. Walker, and S. K. Liston, J. Res. NBS 71A, 371 (1967).

Section D-2.E. PHOTOABSORPTION CROSS SECTIONS (EXTINCTION COEFFICIENTS) FOR Cl_2, Br_2, BrCl, ICl, IBr, HI, and HBr

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D-2.E-1.	Photoabsorption Cross Sections (Extinction Coefficients) for Cl_2, Br_2, BrCl, ICl, and IBr	2032
D-2.E-2.	Photoabsorption Cross Sections (Extinction Ceofficients) for HI and HBr	2033

Tabular Data D-2.E-1. Photoabsorption cross sections (extinction coefficients) for Cl_2, Br_2, BrCl, ICl, and IBr.

Wave length, mμ	Extinction coefficients,[a] $mole^{-1}$ l. $cm.^{-1}$				
	Cl_2	Br_2	BrCl	ICl	IBr
220	...	...	17.5	55.8	9.4
230	...	...	18.8	92.5	14.9
240	0.2	...	16.3	115.1	26.7
250	0.3	...	11.5	113.3	43.7
260	0.6	...	7.7	92.2	56.1
270	2.3	...	4.2	63.7	60.4
280	7.0	...	2.5	40.3	55.2
290	17.0	...	1.4	24.6	44.0
300	31.4	...	1.3	15.9	32.5
310	48.3	...	3.9	12.0	20.8
320	61.8	0.2	10.0	10.5	14.1
330	67.0	0.8	23.6	9.6	8.8
340	61.8	2.9	45.4	8.6	5.6
350	49.6	10.0	71.4	8.1	3.8
360	34.4	23.3	94.9	9.2	4.0
370	21.8	47.6	107.4	13.9	6.2
380	12.9	81.4	106.3	23.0	10.9
390	8.6	119.0	93.7	36.3	18.2
400	5.0	148.9	76.6	49.6	31.5
410	3.5	165.0	60.0	64.5	53.5
420	2.6	165.5	47.9	75.5	83.0
430	1.9	155.5	39.6	83.9	117.1
440	1.4	140.8	34.3	92.7	153.5
450	0.9	127.4	30.2	101.6	188.1
460	...	117.1	26.8	109.0	222.8
470	...	108.4	23.0	111.4	257.6
480	...	101.5	18.6	107.0	290.6
490	...	93.2	14.2	95.0	313.5
500	...	82.9	10.5	77.0	318.2
510	...	70.7	7.4	59.6	303.2
520	...	46.2[b]	...[b]	42.9	269.6
530	...	33.5	...	30.0	224.5
540	...	26.3	...	20.9	176.6
550	...	20.7	...	14.9	136.9
560	...	16.1	...	11.3	95.8
570	...	11.9	...	9.0	71.2
580	...	8.8	...	7.4	52.0
590	...	6.1	...	5.5	38.1
600	...	...	...	4.6	29.6

Note: The extinction coefficient ε is related to the absorption cross section σ by $c\varepsilon/\rho$ where c is the number of moles/liter and ρ is the number density of molecules.

Reference: These data were taken from D.J. Seery and D. Britton, J. Phys. Chem. 68, 2263 (1964).

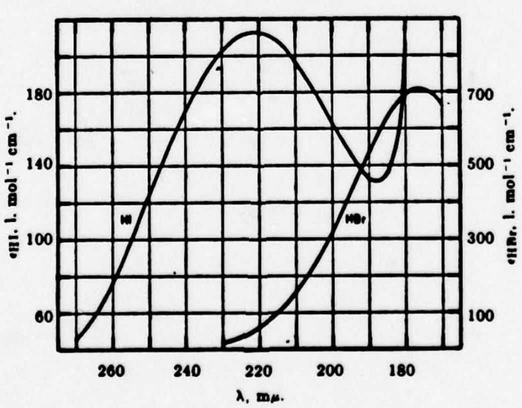
[a] The uncertainty in the values given is about 0.5 except for IBr where it is ~ 2.5.

[b] Discrete absorption of Br_2 begins at 512 mμ and causes an increased uncertainty in the values for Br_2 and BrCl at longer wavelengths.

Tabular and Graphical Data D-2.E-2. Photoabsorption cross sections (extinction coefficients) for HI and HBr.

HBr			HI		
λ, Å	ε, l. mol^{-1} cm^{-1}	δ, l. mol^{-1} cm^{-1}	λ, Å	ε, l. mol^{-1} cm^{-1}	δ, l. mol^{-1} cm^{-1}
2300	20 ± 3		3000	7.4	0.1
2250	30 ± 3		2900	13.6	0.1
2200	62 ± 3		2800	24.9	0.2
2150	102 ± 3		2700	45.3	0.1
2100	154.5	0.8	2600	78.1	0.8
2050	228	0.9	2537	106.8	0.6
2000	319	2.0	2500	124.3	1.2
1950	428	2.2	2400	170.3	0.9
1900	534	3.2	2300	203.5	1.0
1850	633	3.5	2215[b]	212.9	0.5
1800	694	2.0	2100	196.0	0.7
1760[b]	710	1.3	2000	164.1	0.4
1700	665	5.0	1950	146.1	0.9
			1900	133.5	0.5
			1877[c]	130.8	0.8
			1850	134.2	1.2
			1800	207.0	2.0

[a] The 2150–2300-Å values for HBr are based on a single determination and maximum errors are given; the other absorbancy indexes are mean values and δ is the average deviation from the mean. [b] Maximum. [c] Minimum.



Note: The extinction coefficient ε is related to the absorption cross section σ by $\sigma = c\epsilon/\rho$ where c is the number of moles/liter and ρ is the number density of molecules.

Reference: These data were taken from D. J. Seery and D. Britton, J. Phys. Chem. 68, 2263 (1964).

Section D-2.F. PHOTOABSORPTION, PHOTOIONIZATION, AND PHOTODISSOCIATION CROSS SECTIONS OF MOLECULES (MONOMERS): DATA NEEDED

Data are needed for a variety of species in the photon energy range from threshold to 40 eV. Absolute photoabsorption cross sections are needed for F_2 and I_2; data for Cl_2 and Br are needed for wavelengths shorter than 600 Å. Absolute cross sections are also needed for all the molecules for which only relative data are presently available. Data on the photoabsorption of the various molecules formed by Hg, Cd, and U with C, N, O, H, and the halogens (other than UF_6, $HgBr_2$, and HgI_2 where data exist) does not exist. These data could be very important, depending upon the magnitudes of the cross sections, and could be urgently required.

Data for photoabsorption, photoionization, and photodissociation for excited states of molecules are virtually nonexistent. These data, particularly for metastable and other long-lived excited states, are of great importance.

D-3. PHOTOABSORPTION, PHOTOIONIZATION, AND PHOTODISSOCIATION CROSS SECTIONS OF MOLECULES (EXCIMERS)

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Section D-3.A. PHOTOIONIZATION CROSS SECTIONS FOR He_2

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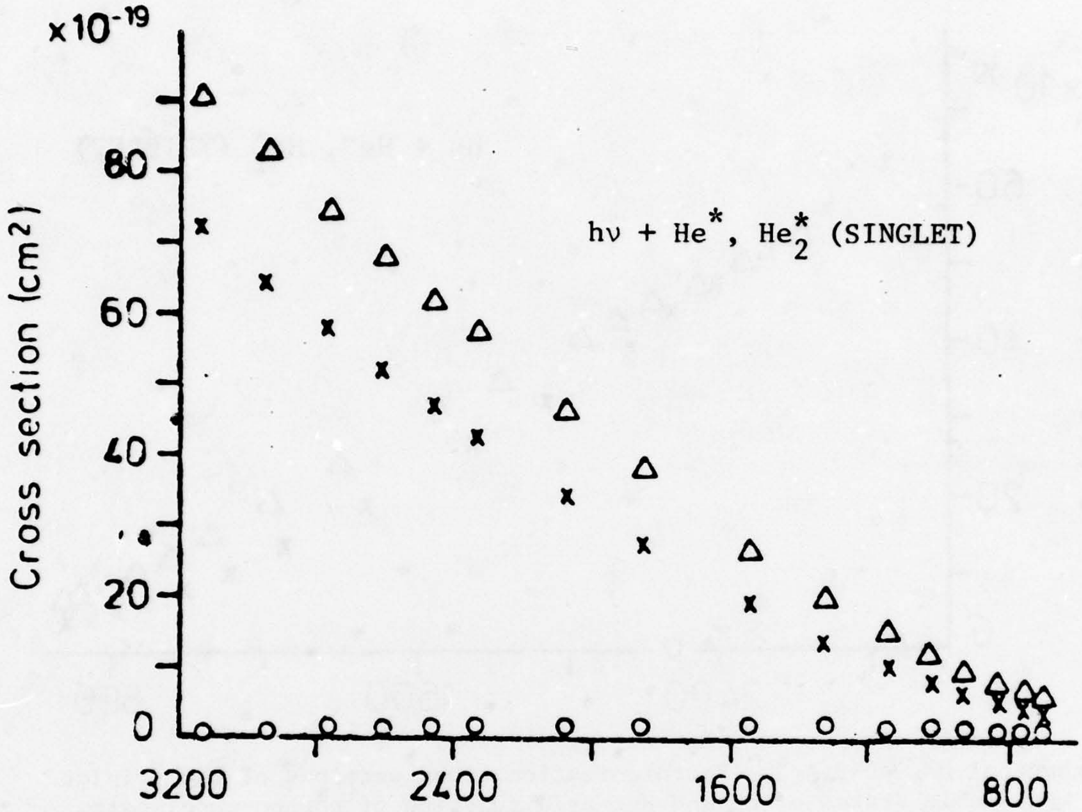
D-3.A-1.	Photoionization cross sections for He_2	2038
D-3.A-2.	Photoionization cross sections of the singlet metastable states of He and He_2 as a function of photon wavelength	2039
D-3.A-3.	Photoionization cross section of the triplet metastable states of He and He_2 as a function of photon wavelength	2040

Tabular Data D-3.A-1. Photoionization cross sections for He_2 (units of $10^{-18} cm^2$).

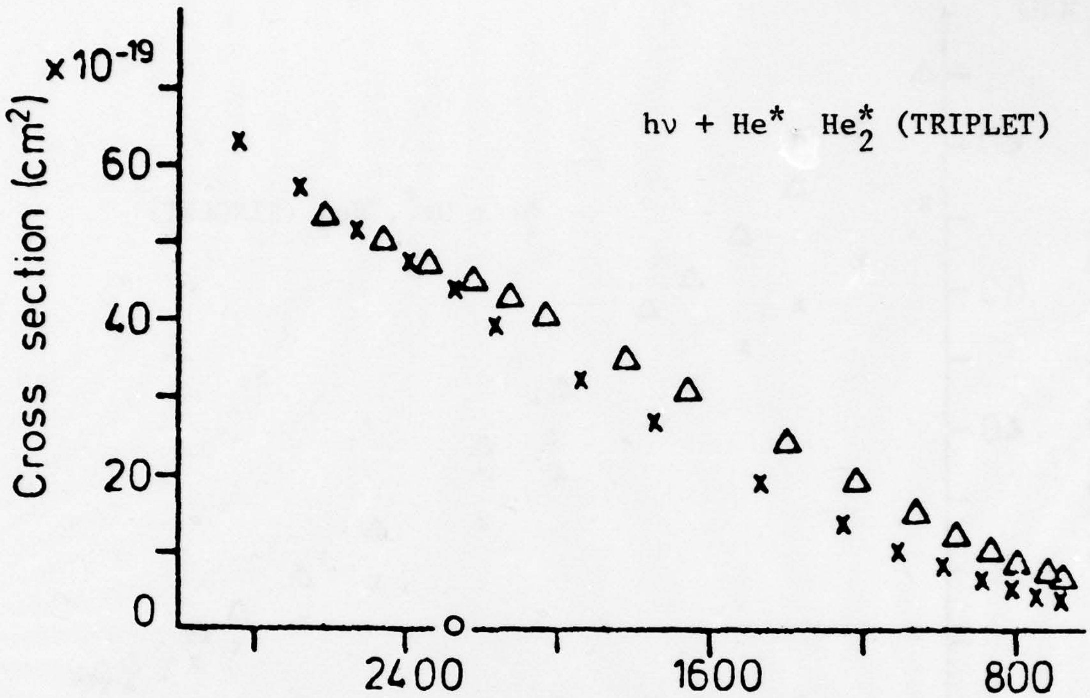
$A^1\Sigma_u^+$ State		$A^3\Sigma_u^+$ State	
Wavelength	Cross Section	Wavelength	Cross Section
3138.2	7.2	2848.2	6.3
2948.1	6.4	2678.9	5.7
2776.0	5.8	2531.6	5.1
2611.7	5.2	2393.0	4.7
2471.1	4.7	2279.7	4.3
2342.4	4.3	2175.3	3.9
2084.4	3.4	1945.2	3.2
1864.0	2.8	1753.1	2.6
1560.7	1.9	1476.0	1.8
1345.3	1.4	1257.6	1.3
1147.3	1.1	1112.9	0.95
1032.0	0.83	992.0	0.73
935.7	0.66	898.1	0.58
834.7	0.54	817.2	0.45
771.0	0.48	752.6	0.39
705.5	0.41	683.5	0.32

Reference: These data were taken from T.W. Hartquist, J. Phys. B 11, 2101 (1978).

Note: The above data are theoretical, obtained using quantum defect theory. The estimated accuracy is ± 20%.



Graphical Data D-3.A-2. Photoionization cross sections of the singlet metastable states of He and He_2 as a function of photon wavelength. $\times$ - $He_2(A^1\Sigma_u^+) \rightarrow p\pi(^1\Pi g)$; o - $He_2(A^1\Sigma_u^+) \rightarrow p\sigma(^1\Pi_g)$; Δ - $He(2^1s)$. These data were taken from T.W. Hartquist, J. Phys. B. 11, 2101 (1978).



Graphical Data D-3.A-3. Photoionization cross sections of the triplet metastable states of He and He_2 as a function of photon wavelength. × - $He_2(A^3\Sigma_u^+) \rightarrow p\pi(^3\Pi_g)$; o - $He_2(A^3\Sigma_u^+) \rightarrow p\sigma(^3\Pi_g)$; Δ - $He(2^3s)$. These data were taken from T.W. Hartquist, J. Phys. B. 11, 2101 (1978).

Section D-3.B. RELATIVE PHOTOIONIZATION CROSS SECTIONS OF VARIOUS RARE GAS - RARE GAS AND RARE GAS - HALOGEN EXCIMERS

Experimental measurements of the photoionization efficiency curves of Ar_2, Kr_2, Xe_2, KrAr, XeAr, XeKr, XeF_2, XeF_4, and XeF_6 are given in Vol. II, pp. 672-680.

Section D-3.C. PHOTOABSORPTION, PHOTOIONIZATION, AND PHOTODISSOCIATION CROSS SECTION OF MOLECULES (EXCIMERS): DATA NEEDED

Experimental measurements of the absolute photoabsorption, photoionization, and photodissociation cross sections for all of the excimers discussed in this section are needed; all the present experimental data are relative and the only absolute data are theoretical.

In addition, data on new excimers, including any that might involve heavy elements of interest (particularly U) is of great importance.

D-4. PHOTODETACHMENT, PHOTODISSOCIATION, AND PHOTODESTRUCTION OF NEGATIVE IONS

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D-4.B.	Photodetachment Cross Sections of H^-, C^-, and O^-	2045
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D-4.F.	Photodestruction Cross Sections of O_2^-, CO_3^-, O_3^-, and O_4^-	2071
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Section D-4.A. PHOTODETACHMENT CROSS SECTIONS OF F^-, Cl^-, Br^-, AND I^-

Experimental data on the photodetachment cross sections of F^-, Cl^-, Br^-, and I^- is given in detail in Vol. II, pp. 682-683. The data are given in the 2000-4000 Å range, i.e., photon energy from 3-6 eV. No new data have since been reported.

Section D-4.B. PHOTODETACHMENT CROSS SECTIONS OF H^-, C^-, AND O^-

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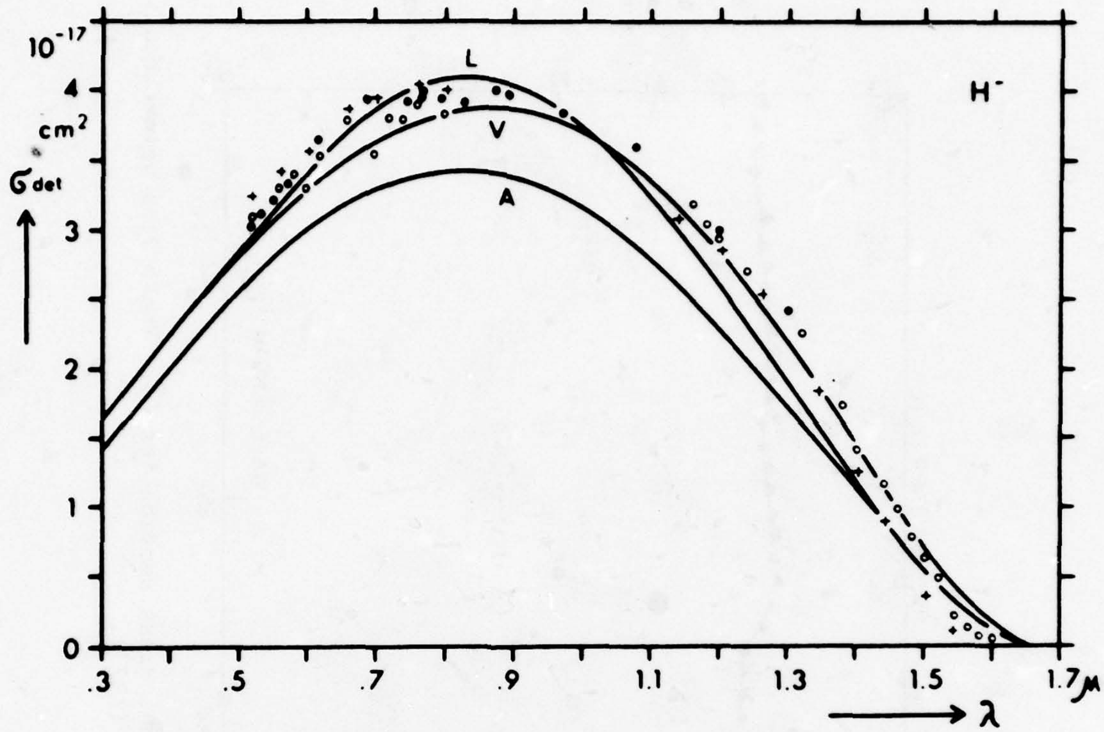
Tabular Data D-4.B-1. Photodetachment cross sections for H^- and C^- (units of $10^{-18} cm^2$).

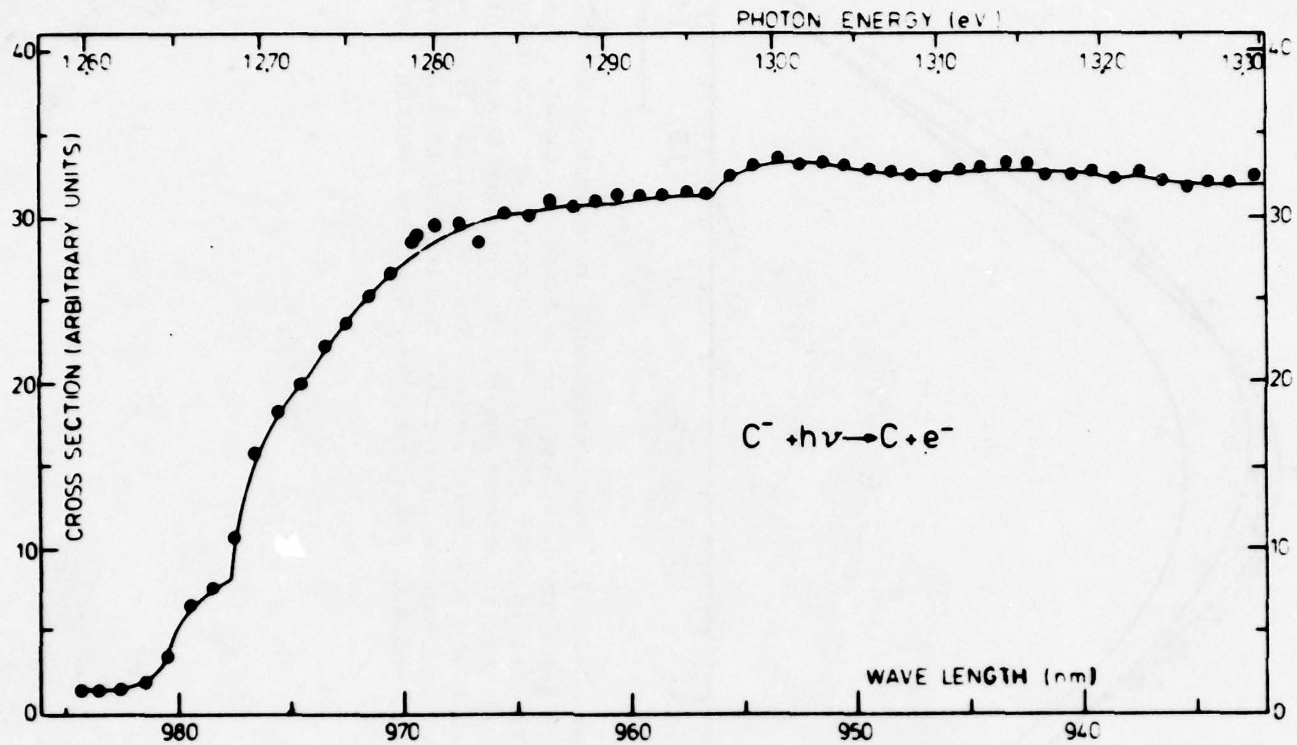
λ(Å)	hν(eV)	H^-	C^-
16,000	0.775	0.59	
14,000	0.886	11.	
12,000	1.03	25.	
10,000	1.25	37.	0.29
8000	1.55	41.	14.
6000	2.07	34.	14.
4000	3.10	22.	13.
3000	4.13	16.	
2000	6.20	1.9	
1500	8.27	6.9	
1000	12.4	22.	
970	12.8	27.	
900	13.8	5.3	
800	15.5	3.9	
600	20.7	1.2	
500	24.8	0.81	

References: The above data for H^- were taken from H.P. Popp and S. Kruse, J. Quant. Spectrosc. Radiat. Transfer 16, 683 (1976) and for C^- from D. Feldmann, Z. Naturforsch. 25a, 621 (1970).

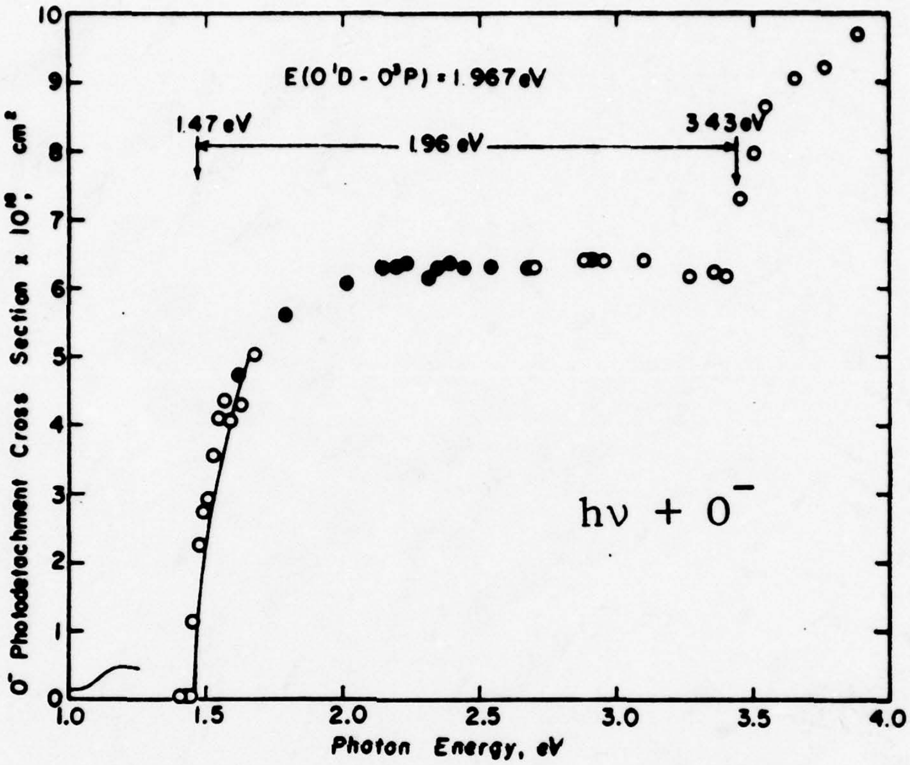
Note: The accuracy of these data is ±10%.



Graphical Data D-4.B-2. Photodetachment cross section for H^-. These data were taken from H.P. Popp and S. Kruse, J. Quant. Spectrosc. Radiat. Transfer 16, 683 (1976). The circles and crosses are the experimental results of that paper, the dots are experimental results of S.J. Smith and D.S. Burch, Phys. Rev. 116, 1125 (1959) and the solid lines are various theoretical results due to N.A. Doughty, P.A. Fraser, and R.C. McEachran, Mon. Not. Roy. Astron. Soc. 132, 255 (1966).



Graphical Data D-4.B-3. Relative photodetachment cross section for C^-. These data were taken from D. Feldmann, Chem. Phys. Letts. 47, 338 (1977).



Graphical Data D-4.B-4. Photodetachment cross section for O^-. These data were taken from L.M. Brancomb, S.J. Smith, and G. Tisone, J. Chem. Phys. 43, 2906 (1965).

Section D-4.C. PHOTODETACHMENT CROSS SECTIONS OF O_2^-, CO_3^-, OH^-, OD^-, NH_2^-, CH^-, C_2^-, C_2H^-, CH_2^-, CH_3^-, NO_2^{-*}

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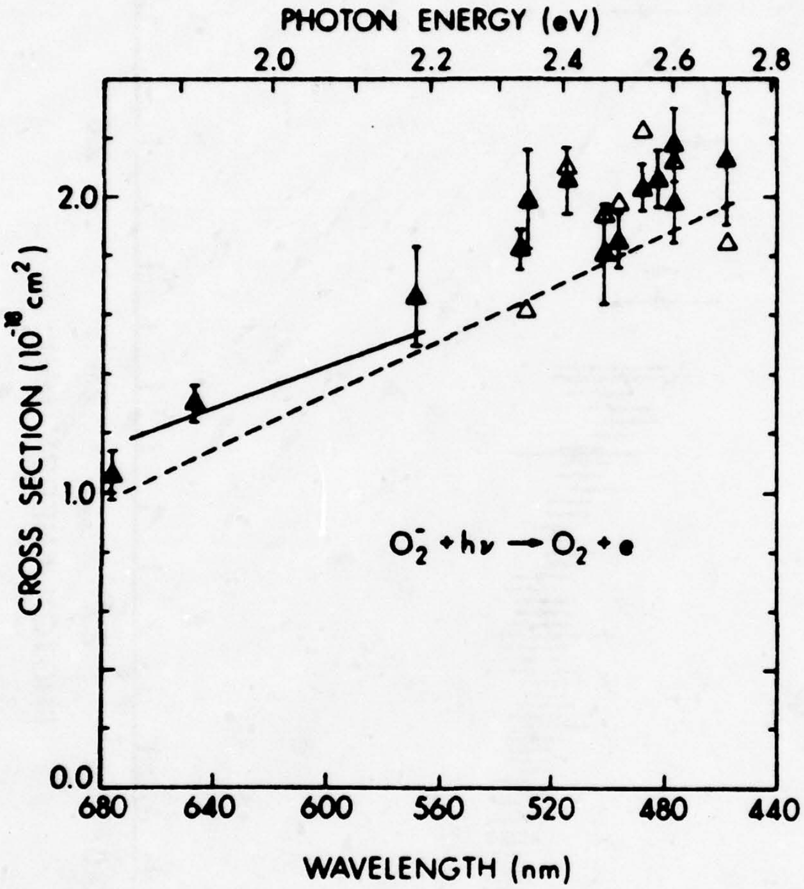
Tabular Data D-4.C-1. Photodetachment cross section for O_2^- (units of $10^{-18} cm^2$).

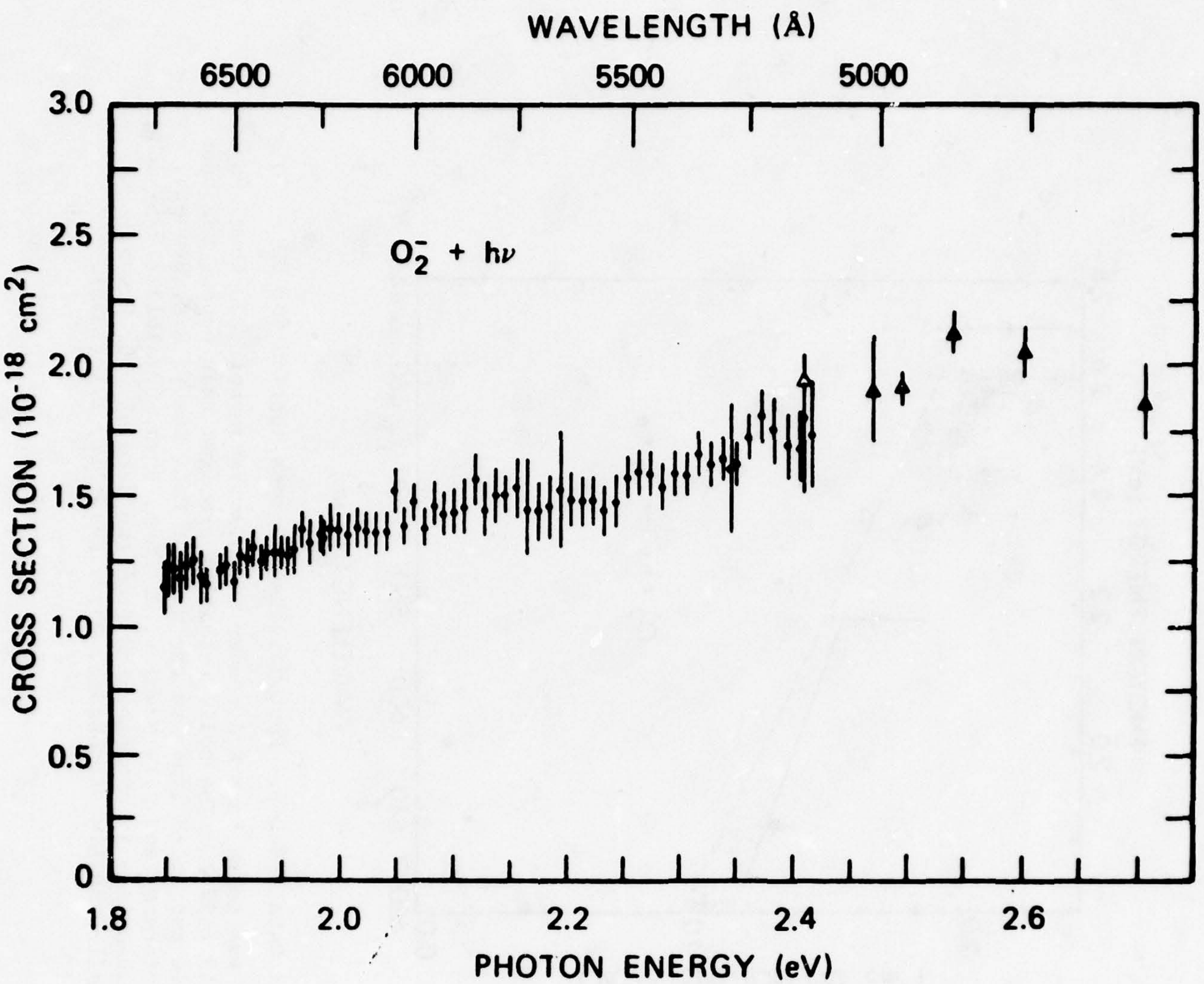
λ(Å)	$h\nu$(eV)	σ
20000	0.62	0.043
16000	0.775	0.14
12000	1.03	0.27
10000	1.24	0.43
9000	1.38	0.56
8600	1.44	0.60
8400	1.48	0.66
8000	1.55	0.73
7200	1.72	0.90
6800	1.82	1.0
6400	1.94	1.1
6000	2.07	1.3
5600	2.21	1.5
5200	2.38	1.7
4800	2.58	2.0
4400	2.82	2.3
4200	2.95	2.4

Reference: These data were taken from R. A. Bexer and J. A. Vanderhoff, J. Chem. Phys. 65, 2313 (1976) and P. C. Cosby, J. H. Ling, J. R. Peterson, and J. T. Moseley, J. Chem. Phys. 65, 5267 (1976).

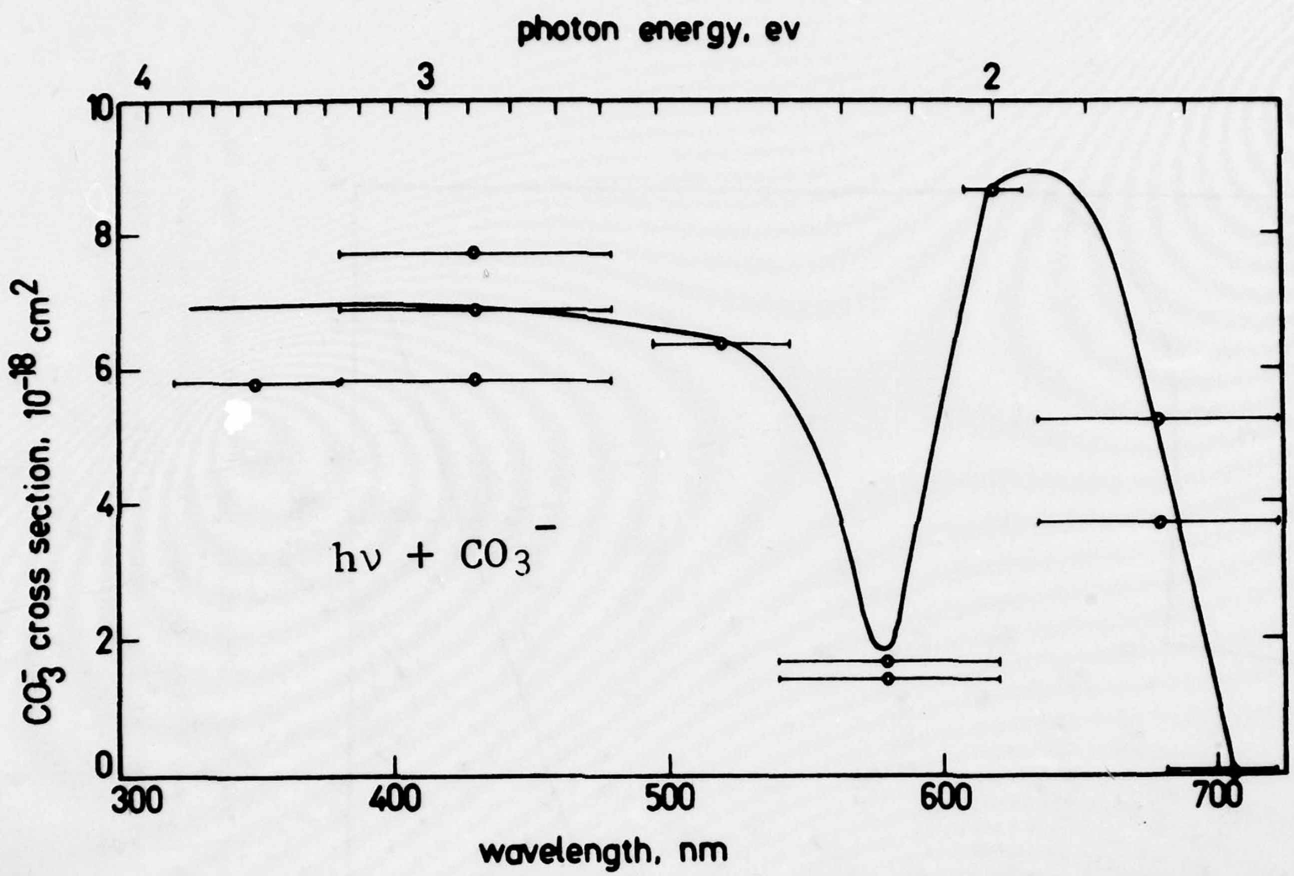
Note: The accuracy of these data is ±15%.



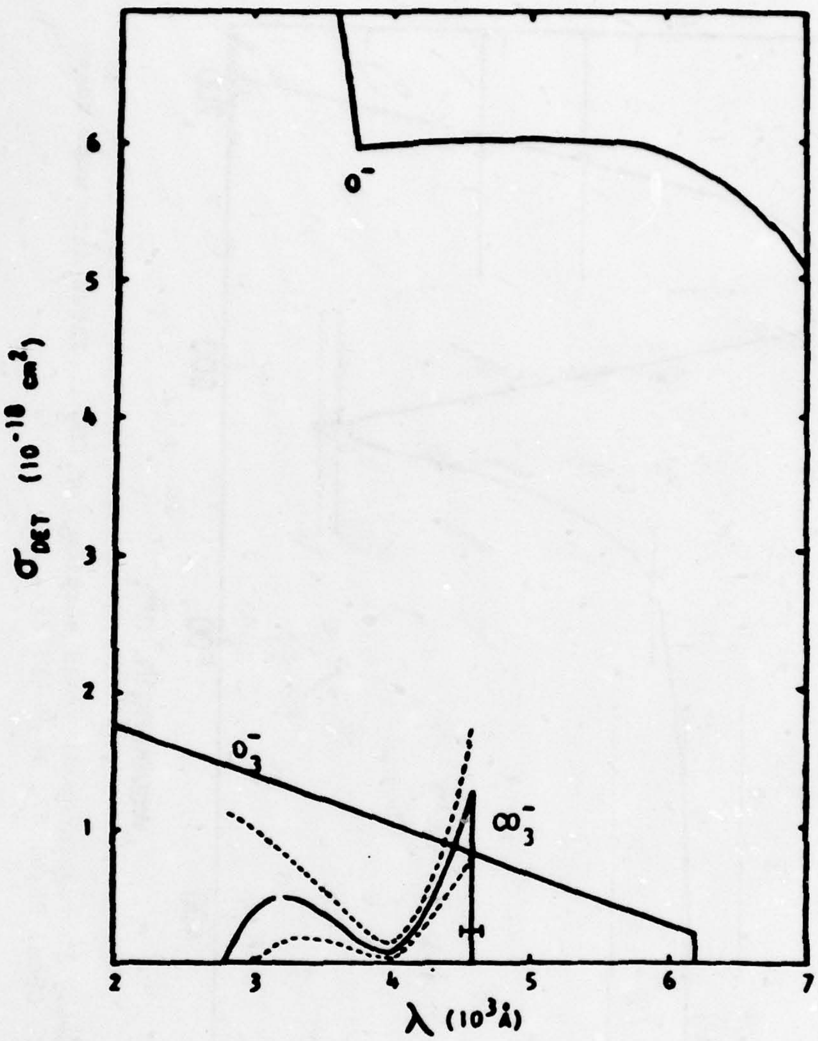
Graphical Data D-4.C-2. Photodetachment cross section for O_2^-. This figure was taken from R.A. Beyer and J.A. Vanderhoff, J. Chem. Phys. 65, 2313 (1976). The solid triangles are from that paper, the open triangle and solid line are the data of P.C. Cosby, R.A. Bennett, J.R. Peterson, and J.T. Moseley, J. Chem. Phys. 63, 1612 (1975) and the dashed line is extrapolated from the data of D.D. Burch, S.J. Smith, and L.M. Branscomb, Phys. Rev. 112, 171 (1958).



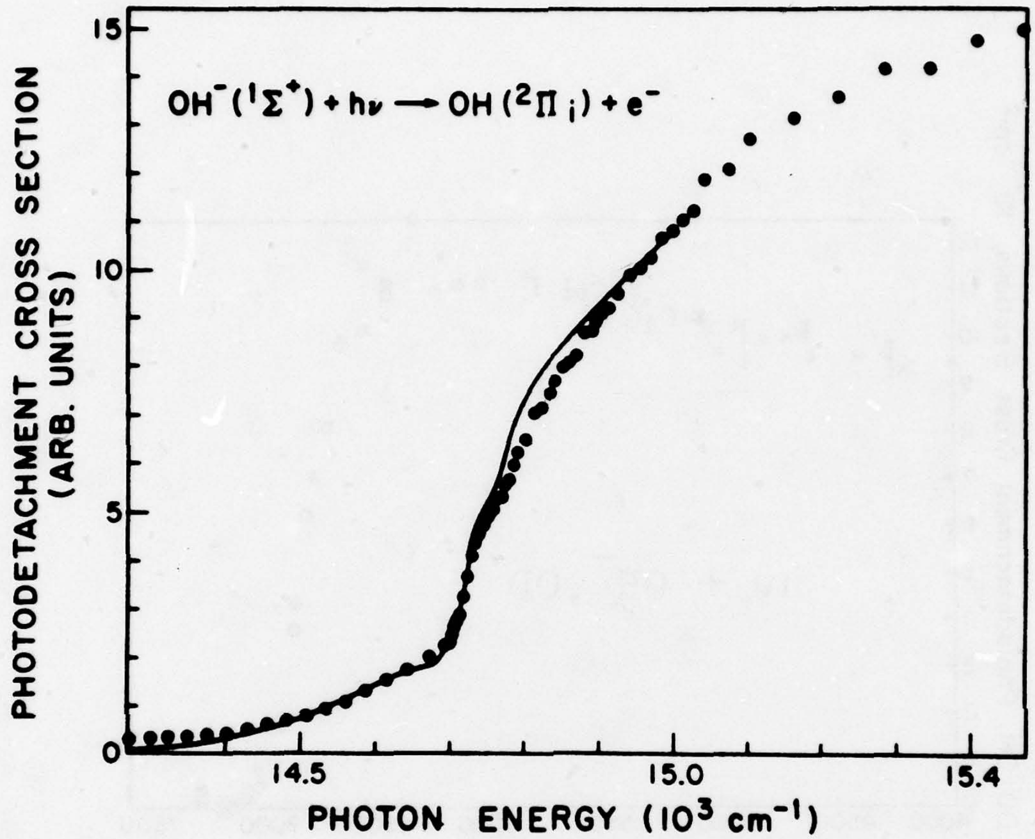
Graphical Data D-4.C-3. Photodetachment cross section of O_2^-. These data were taken from P.C. Cosby, J.H. Ling, J.R. Peterson, and J.T. Moseley, J. Chem. Phys. 65, 5267 (1976).



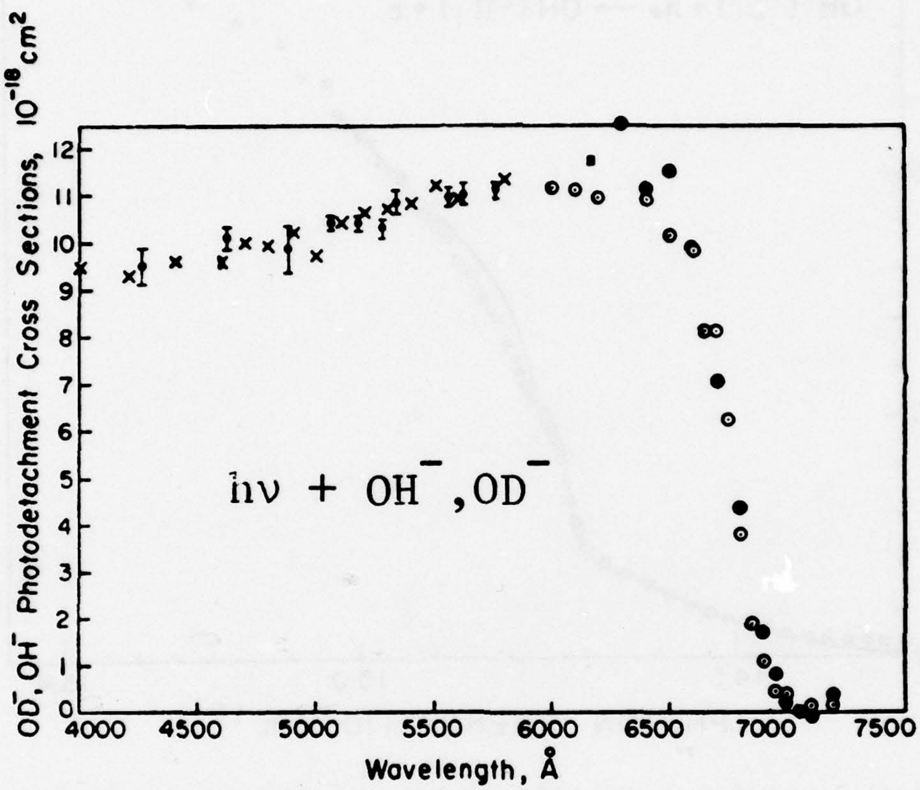
Graphical Data D-4.C-4. Photodetachment cross section for CO_3^-. These data were taken from J. A. Burt, J. Chem. Phys. 57, 4649 (1972).



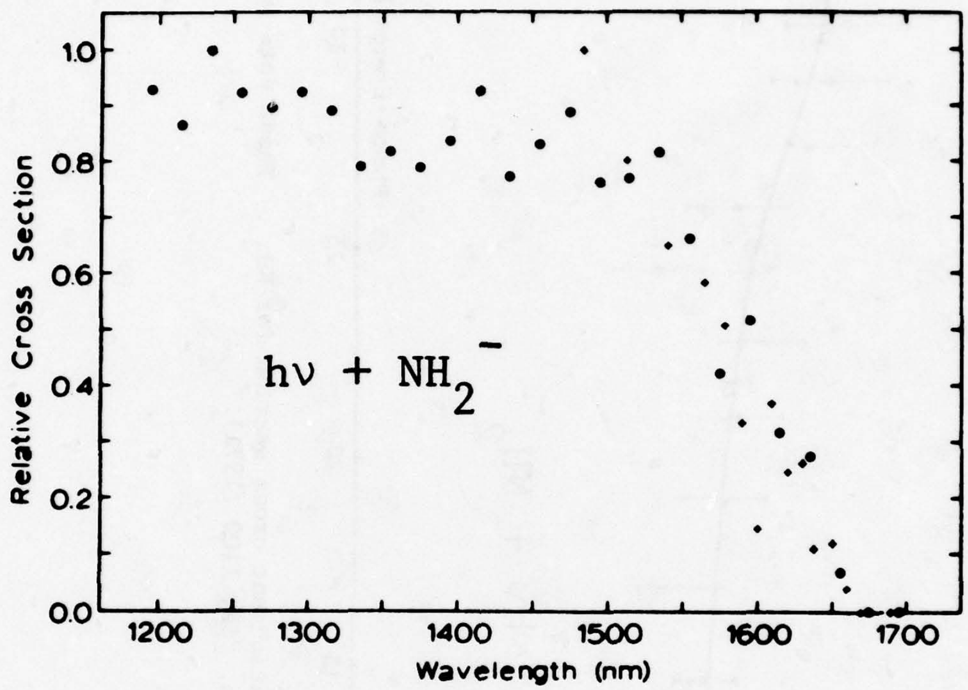
Graphical Data D-4.C-5. Photodetachment cross section for CO_3^- along with O_3^- and O^- for comparison. The dashed curves are one standard deviation plus and minus. These data were taken from S.P. Hong, S.B. Woo, and E.M. Helmy, Phys. Rev. A 15, 1563 (1977).



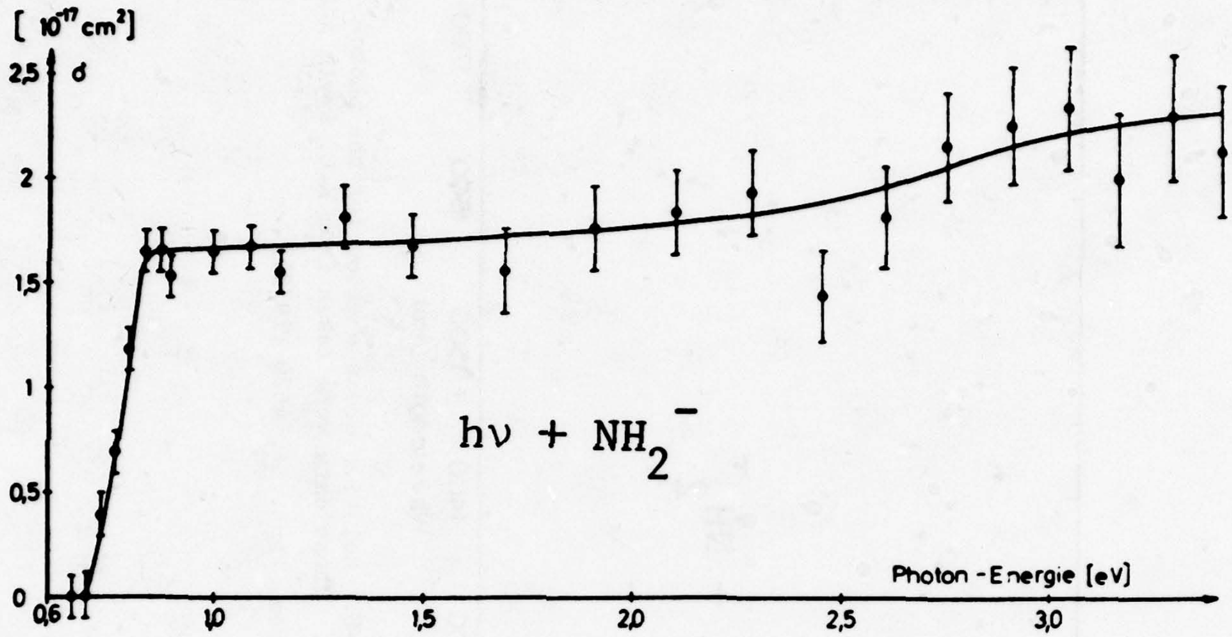
Graphical Data D-4.C-6. Photodetachment cross section for OH^-. The solid line is a fit to the data which were taken from H. Hotop, T.A. Patterson, and W.C. Lineberger, J. Chem. Phys. 60, 1806 (1974).



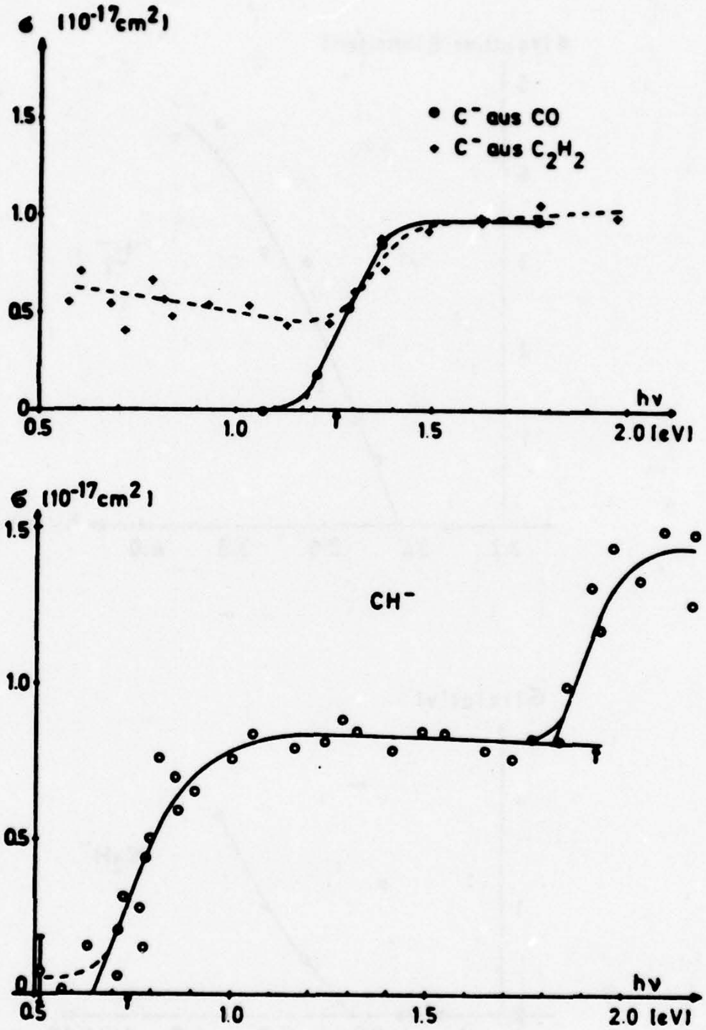
Graphical Data D-4.C-7. Photodetachment cross section for OH^- (solid points) and OD^- (crosses and circles). These data were taken from L.M. Branscomb, Phys. Rev. 148, 11 (1966).



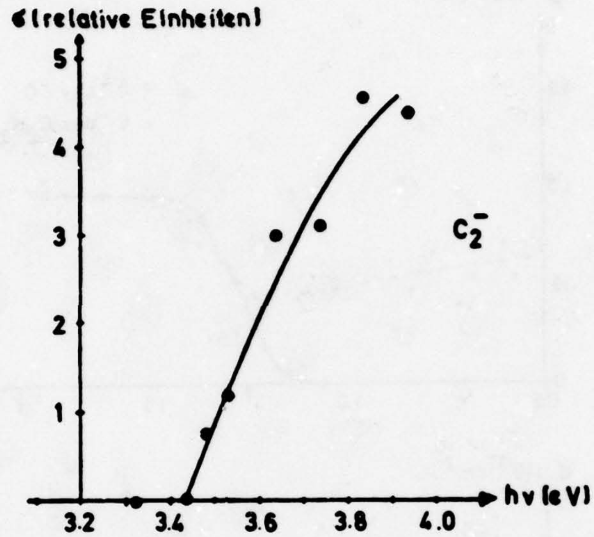
Graphical Data D-4.C-8. Relative cross section for the photodetachment of NH_2^-. These data were taken from K.C. Smyth and J.I. Brauman, J. Chem. Phys. 56, 4620 (1972).

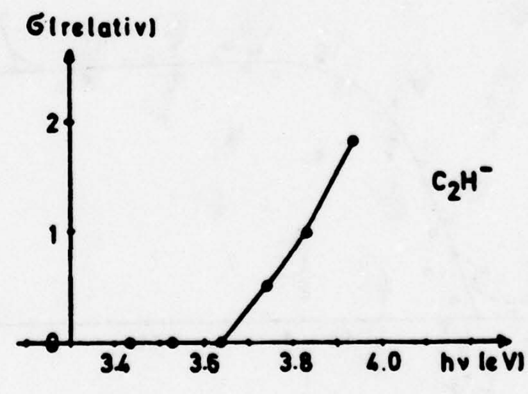


Graphical Data D-4.C-9. Photodetachment cross section for NH_2^-. These data were taken from D. Feldmann, Zeit. Naturforsch. 26a, 1100 (1971).

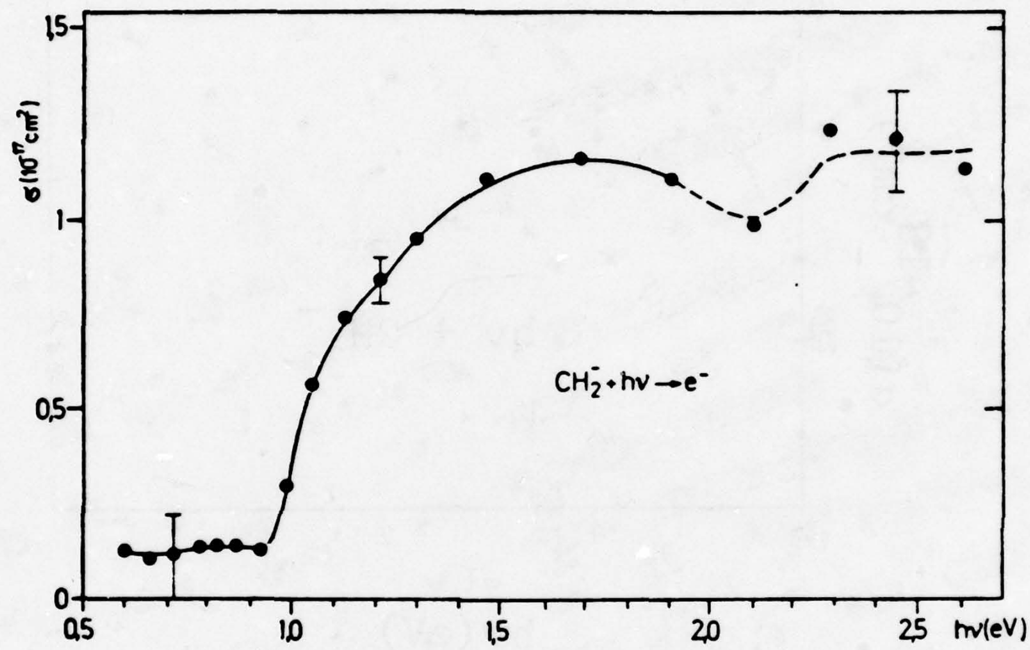


Graphical Data D-4.C-10. Photodetachment cross sections for C^- and CH^-. These data were taken from D. Feldmann, Zeit. Naturforsch. 25a, 621 (1970).

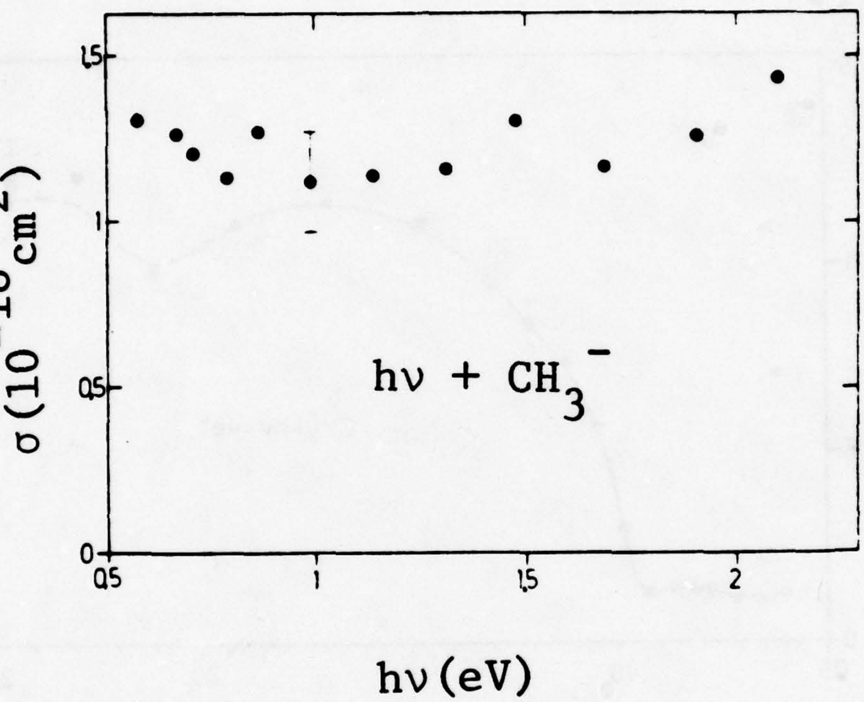




Graphical Data D-4.C-11. Relative photodetachment cross section for C_2^- and C_2H^-. These data were taken from D. Feldmann, Zeit. Naturforsch. 25a, 621 (1970).

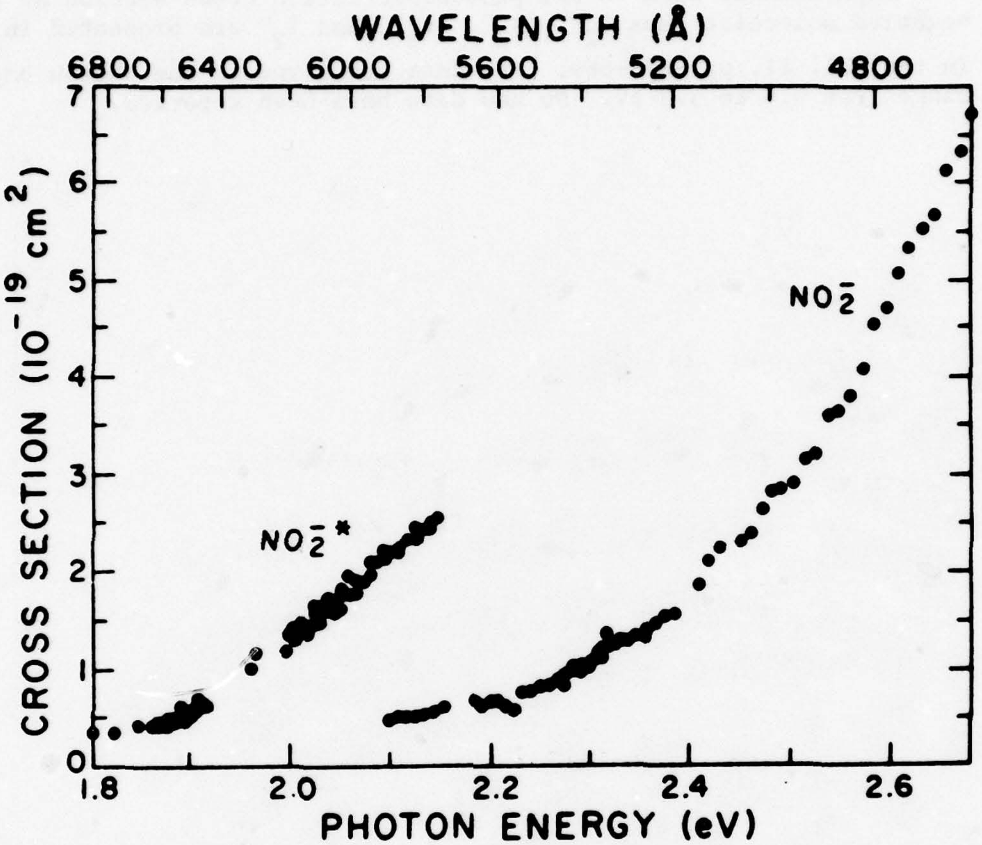


Graphical Data D-4.C-12. Photodetachment cross section for CH_2^-.
These data were taken from D. Feldmann, R. Rackwitz, H.J. Kaiser, and E. Heinicke, Zeit. Naturforsch. 32a, 600 (1977).



Graphical Data D-4.C-13. Photodetachment cross section for CH_3^-.

These data were taken from D. Feldmann, R. Rackwitz, H.J. Kaiser, and E. Heinicke, Zeit. Naturforsch. 32a, 600 (1977).



Graphical Data D-4.C-14. Photodetachment cross section for NO_2^- and NO_2^{-*}. The relative values have been measured to $\pm10\%$, but the absolute values are known only to $\pm40\%$. These data were taken from E. Herbst, T.A. Patterson, and W.C. Lineberger, J. Chem. Phys. 61, 1300 (1974).

Section D-4.D. PHOTODISSOCIATION OF F_2^-, Cl_2^-, Br_2^-, and I_2^-

Experimental data on the photodissociation cross section of the negative molecular ions F_2^-, Cl_2^-, Br_2^-, and I_2^- are presented in detail in the Vol. II, pp. 688-689. The data are given in the photon energy range from 0.6 to 3.3 eV. No new data have been reported.

Section D-4.E. PHOTODISSOCIATION CROSS SECTIONS OF O_3^-, CO_3^-, AND CO_4^-

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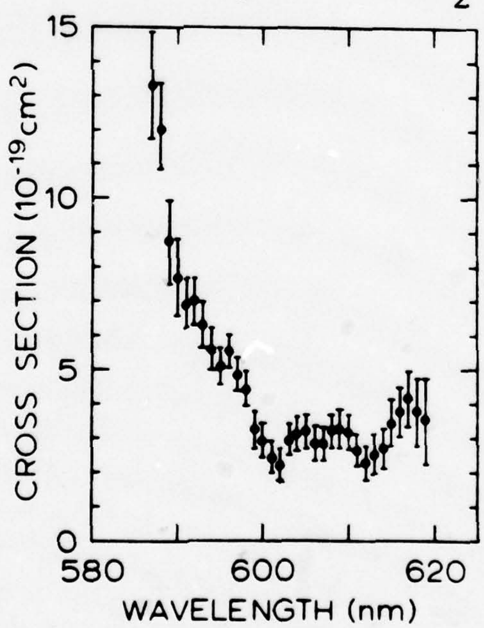
Tabular and Graphical Data D-4.E-1. Photodissociation cross section for O_3^- (units fo $10^{-19} cm^2$).

λ(nm)	O^-	O_2^-
305	< 1	< 1
365	2.2 ± 0.7	1.2 ± 1
405	15 ± 2	15 ± 2
435	59 ± 2	30 ± 2
550	31 ± 1	1.1 ± 0.7
580	12 ± 1	< 1
590	4.5 ± 0.5[a]	< 1
600	1.8 ± 0.3[a]	< 1
610	1.3 ± 0.3[a]	< 1

[a]Obtained using tunable dye laser at ion source pressure of 0.1 torr; in this range a significant decrease in cross section with increasing source pressure was observed.

$h\nu + O_3^- \rightarrow O^- + O_2$



Note: The above data are for the reactions $h\nu + O_3^- \rightarrow O^- + O_2$ and $h\nu + O_3^- \rightarrow O_2^- + O$.

Reference: These data were taken from M.L. Vestal and G.H. Mauclaire, J. Chem. Phys. 67, 3767 (1977).

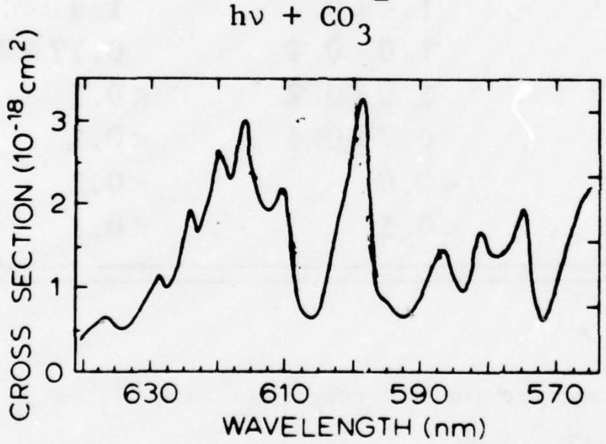
Tabular and Graphical Data D-4.E-2. Photodissociation cross section for CO_3^- (units of $10^{-19} cm^2$).

Photodissociation cross sections for the reaction $CO_3^- \rightarrow O^- + CO_2$.

Wavelength (nm)	Cross section (10^{-19} cm^2)	
	0.1[a]	1.0[a]
305	<0.5	<0.5
365	1 ± 0.6	1 ± 0.6
405	2 ± 0.3	4 ± 1
435	7 ± 1	13 ± 1.5
550	1 ± 0.5	5.4 ± 0.5
580	0.3 ± 0.1	1.6 ± 0.2

[a] Ion source pressure in torr.

hν + CO_3^-



Reference: These data were taken from M.L. Vestal and G.H. Mauclaire, J. Chem. Phys. 67, 3762 (1977).

Tabular Data D-4.E-3. Photodissociation cross section for CO_4^- (units of $10^{-19} cm^2$).

Photodissociation cross sections for the reactions $CO_4^- \rightarrow O_2^- + CO_2$ and $CO_4^- \rightarrow CO_3^- + O$.

Wavelength (nm)	Cross section ($10^{-19} cm^2$)	
	O_2^-	CO_3^-
305	1.4±0.7	1.4±0.1
365	1.0±0.4	0.17±0.04
405	1.0±0.7	<0.1
530	0.7±0.4	<0.1
580	<0.6	<0.1
600	<0.1	<0.1

Note: The above data are for the reactions $h\nu + CO_4^- \rightarrow O_2^- + CO_2$ and $h\nu + CO_4^- \rightarrow CO_3^- + O$.

Reference: These data were taken from M.L. Vestal and G.H. Mauclaire, J. Chem. Phys. 67, 3762 (1977).

Section D-4.F. PHOTODESTRUCTION CROSS SECTIONS FOR O_2^-, CO_3^-, O_3^- and O_4^-

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D-4.F-2. Photodestruction cross section of CO_3^- 2073

D-4.F-3. Photodestruction cross section of O_3^- 2074

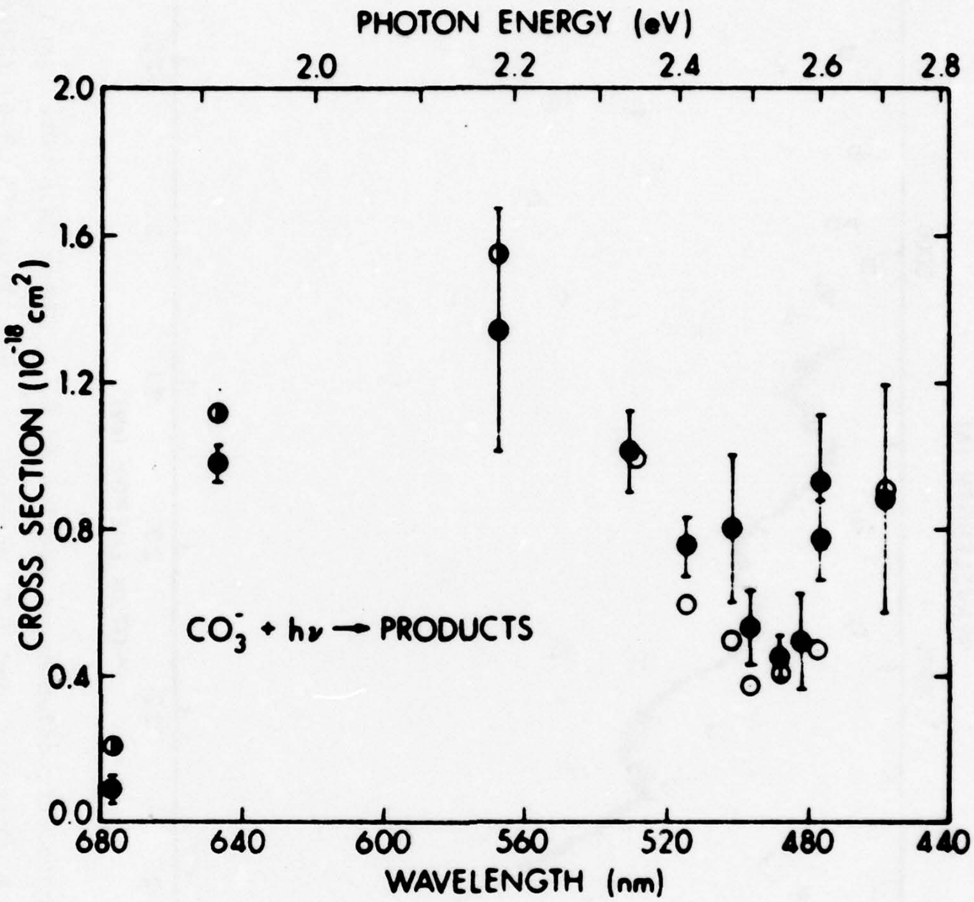
D-4.F-4. Photodestruction cross section of O_4^- 2075

D-4.F-5. Photodestruction cross section of O_4^- 2076

Tabular Data D-4.F-1. Photodestruction cross sections for O_2^- and CO_3^- (units of $10^{-22} m^2$).

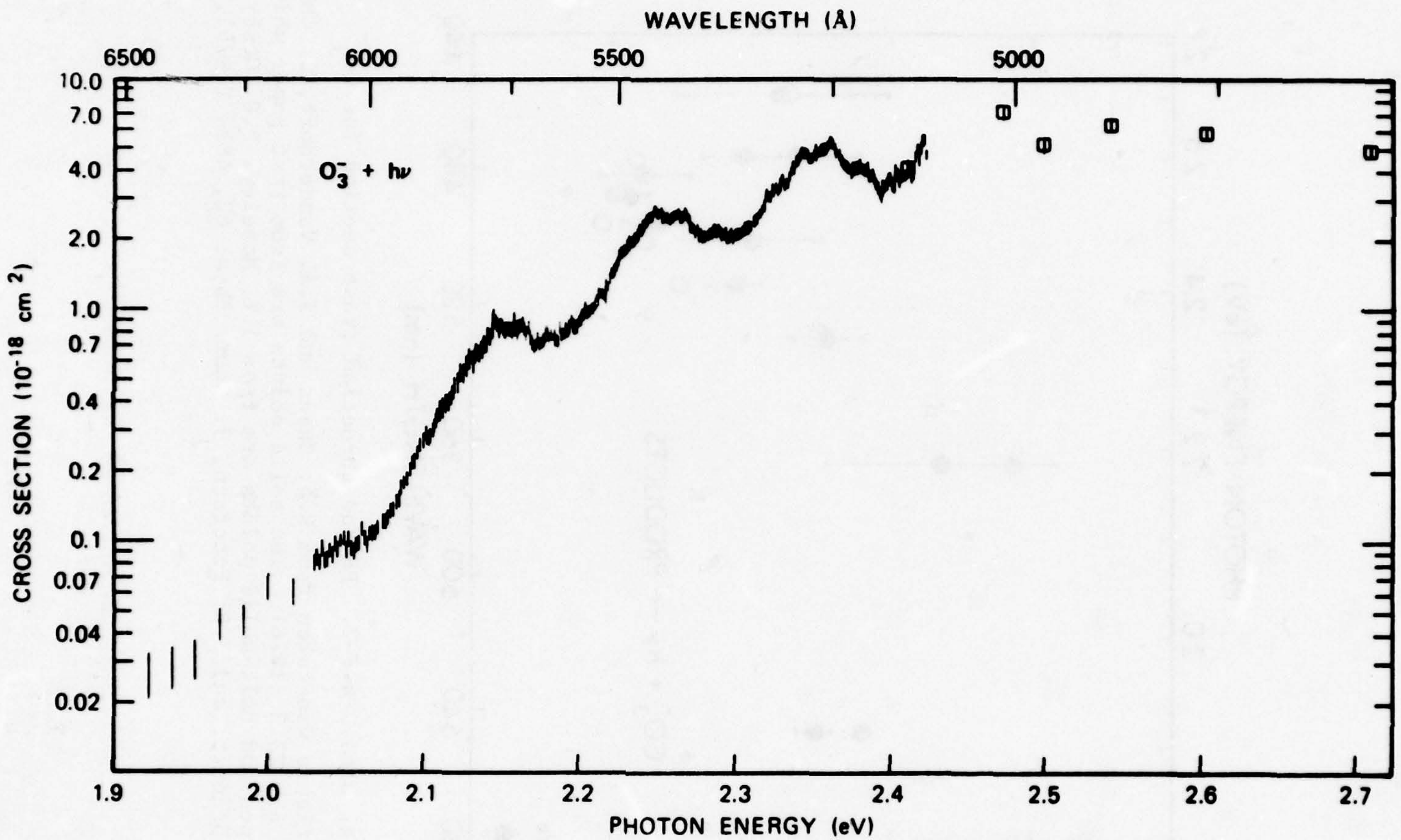
Energy (eV)	$\sigma_{O_2^-}$ (10^{-22} m^2)	$\pm \Delta\sigma_{O_2^-}$ (10^{-22} m^2)	$\sigma_{CO_3^-}$ (10^{-22} m^2)	$\pm \Delta\sigma_{CO_3^-}$ (10^{-22} m^2)
1.833	1.06	0.08	0.09	0.04
1.916	1.30	0.06	0.98	0.05
2.182	1.66	0.17	1.34	0.33
2.335	1.82	0.07	1.01	0.11
2.345	1.99	0.17	...	...
2.410	2.06	0.12	0.75	0.08
2.471	1.80	0.17	0.80	0.20
2.497	1.85	0.10	0.53	0.10
2.540	2.03	0.08	0.45	0.06
2.569	2.06	0.10	0.49	0.13
2.602	2.18	0.13	0.77	0.11
2.603	1.98	0.14	0.93	0.18
2.707	2.13	0.23	0.88	0.31

Reference: These data were taken from R.A. Beyer and J.A. Vanderhoff, J. Chem. Phys. 65, 2313 (1976).

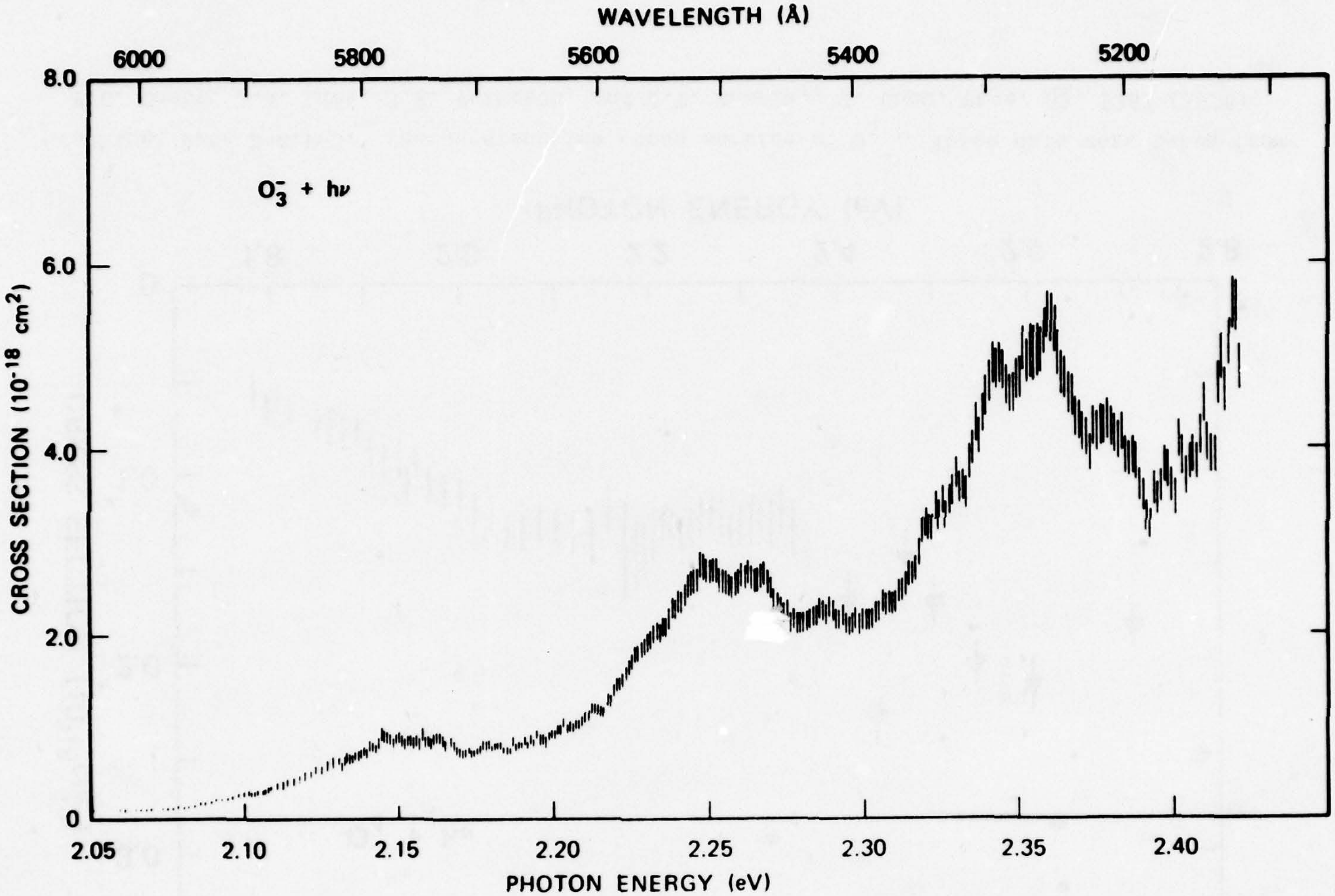


Graphical Data D-4.F-2. Photodestruction cross section for CO_3^-.

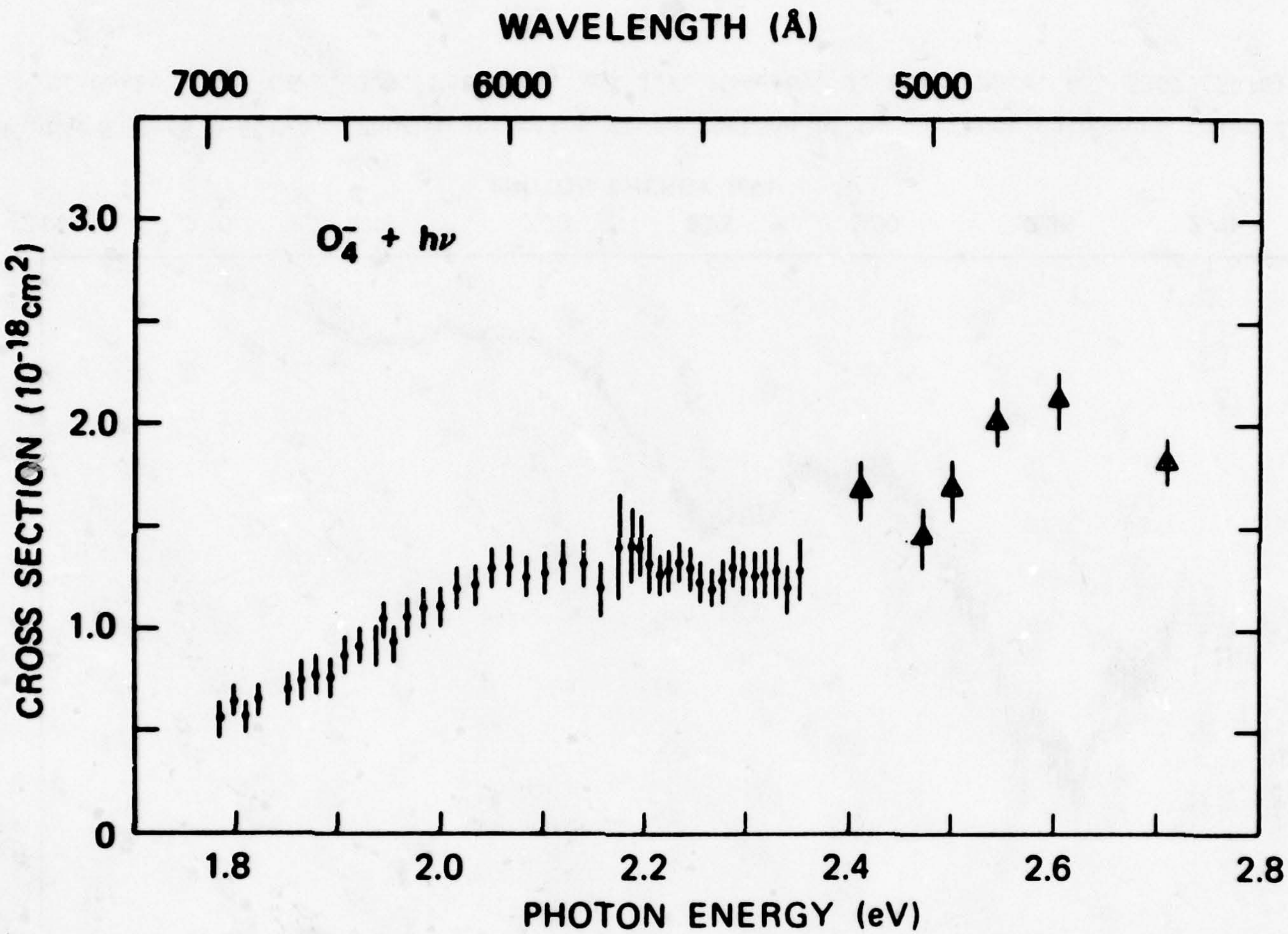
This figure was taken from R.A. Beyer and J.A. Vanderhoff, J. Chem. Phys. 65, 2313 (1976). The solid points are from that paper while the open and half-solid points are from J.T. Moseley, P.C. Cosby, R.A. Bennett, and J.R. Peterson, J. Chem. Phys. 62, 4826 (1975).



Graphical Data D-4.F-3. Photodestruction cross section of O_3^-. These data were taken from P.C. Cosby, J.H. Ling, J.R. Peterson, and J.T. Moseley, J. Chem. Phys. 65. 5267 (1976).



Graphical Data D-4.F-4. Photodestruction cross section of O_3^-. These data were taken from P.C. Cosby, J.H. Ling, J.R. Peterson, and J.T. Moseley, J. Chem. Phys. 65, 5267 (1976).



Graphical Data D-4.F-5. Photodestruction cross section of O_4^-. These data were taken from P.C. Cosby, J.H. Ling, J.R. Peterson, and J.T. Moseley, J. Chem. Phys. <u>65</u>, 5267 (1976).

Section D-4.G. PHOTODETACHMENT, PHOTODISSOCIATION, AND PHOTODESTRUCTION OF NEGATIVE IONS: DATA NEEDED

The primary data needed in this area are for cross sections for the negative molecular ions containing Cd, Hg, and (especially) U. No data exist for any such ions for photodetachment, photodissociation, or photodestruction; in fact, which negative molecular ions containing the atoms exist is not at all well known. This is a fairly high priority item and should be investigated.

D-5. FREE-FREE ABSORPTION COEFFICIENTS

Free-free absorption coefficients for He, Ne, Ar, Kr, Xe, and Cl are given in Vol. II, pp. 692-693. The data presented are theoretical. No new results have been reported.

This is not a high priority item, but it would be useful if data were available for the rest of the halogen atoms. In addition, some experimental data to pin down the accuracy of the calculated values would be resonably useful.

E. TRANSPORT PROPERTIES OF ELECTRONS, IONS, AND NEUTRALS IN GASES

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E-1. TRANSPORT PROPERTIES OF ELECTRONS

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General References

J. Dutton, "A Survey of Electron Swarm Data," J. Phys. Chem. Ref. Data 4, No. 3, 577-856 (1975).

M. T. Elford, "Precision Measurements of Electron Transport Coefficients," in E. W. McDaniel and M. R. C. McDowell (Eds.) "Case Studies in Atomic Collision Physics," 2, 94, North-Holland, Amsterdam (1972).

A. Gilardini, "Low Energy Collisions in Gases," Wiley, New York (1972).

S. C. Haydon, "Ionization Coefficients and Prebreakdown Phenomena," Physics Reports (1980).

L. G. H. Huxley and R. W. Crompton, "The Diffusion and Drift of Electrons in Gases," Wiley, New York (1974.

W. H. Long, W. F. Bailey, and A. Garscadden, "Electron Drift Velocities in Molecular-Gas-Rare-Gas Mixtures," Phys. Rev. A 13, 471 (1976).

H. S. W. Massey and E. H. S. Burhop, "Electronic and Ionic Impact Phenomena," Vol. 1, Clarendon, Oxford (1969).

H. S. W. Massey, "Negative Ions," Cambridge University Press, New York (1976).

A. von Engel, "Ionization in Gases by Electrons in Electric Fields," in S. Flugge (Ed.), "Encyclopedia of Physics - Vol. XXI Electron Emission, Gas Discharges 1," 504, Springer-Verlag, Berlin (1956).

J. H. Jacob and J. A. Mangano, "Total Electron Impact Excitation Cross Sections of Ar and Kr," Appl. Phys. Letts. 29, 467 (1976).

J. M. Meek and J. D. Craggs, "Electrical Breakdown of Gases," Wiley New York (1976).

S. L. Lin, R. E. Robson, and E. A. Mason, "Moment Theory of Electron Drift and Diffusion in Neutral Gases in an Electrostatic Field," Jour. Chem. Phys. (Sept. 1979).

Definitions and Relationships

v_d Drift velocity of electrons = average velocity along the field direction in a gas exposed to a constant, uniform electric field E. v_d is usually expressed in units of cm/sec.

K Mobility of the electrons, defined by $K = v_d/E$. K is usually expressed in $cm^2/V\text{-}sec$.

E/N Electron energy parameter = ratio of the electric field intensity to the gas number density. E/N is usually expressed in units of $V\text{-}cm^2$, or in Townsends, where 1 Td = 10^{-17} $V\text{-}cm^2$.

Td Unit of E/N, the "Townsend" = 10^{-17} $V\text{-}cm^2$.

D Diffusion coefficient of the electrons. A scalar at low E/N, D is then related to the mobility by the Einstein (or Nernst-Townsend) relation $K = eD/kT$, where T is the gas temperature, e the electronic charge, and k the Boltzmann constant. At higher E/N, D is a tensor quantity.

D_T The component of the diffusion tensor perpendicular to the electric field.

D_L The component of the diffusion tensor parallel to the electric field.

D_T/K and D_L/K are measures of the average electron energy at a given E/N. In the limit $E/N \rightarrow 0$, $D_L = D_T = D$, the scaler diffusion coefficient.

α The first Townsend ionization coefficient. Usually it is expressed as α/N, which then has units of cm^2.

a The electron attachment coefficient, usually expressed as a/N, which has units of cm^2.

For electrons in a given gas at a given temperature, v_d, NK, ND_L, ND_T, α/N, a/N, and the average electron energy are functions of E/N alone, N being the gas number density.

Before about 1970, the energy parameter was usually expressed in terms of E/p, where p is the gas pressure in units of torr. To convert from E/p to E/N, one may use the relation

$$E/N \text{ (in Td)} = (1.0354 \times T \times 10^{-2})\ (E/p)$$

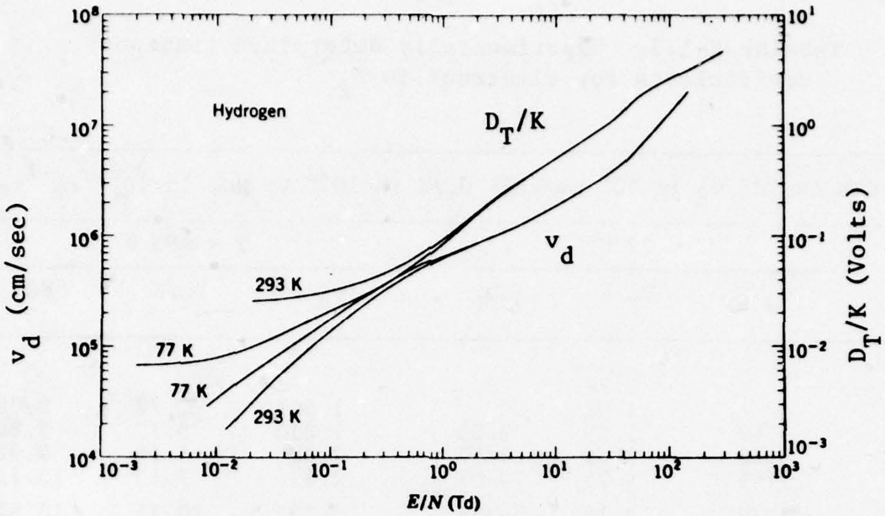
where T is the gas temperature.

Tabular Data E-1.1. Experimentally determined transport coefficients for electrons in H_2.

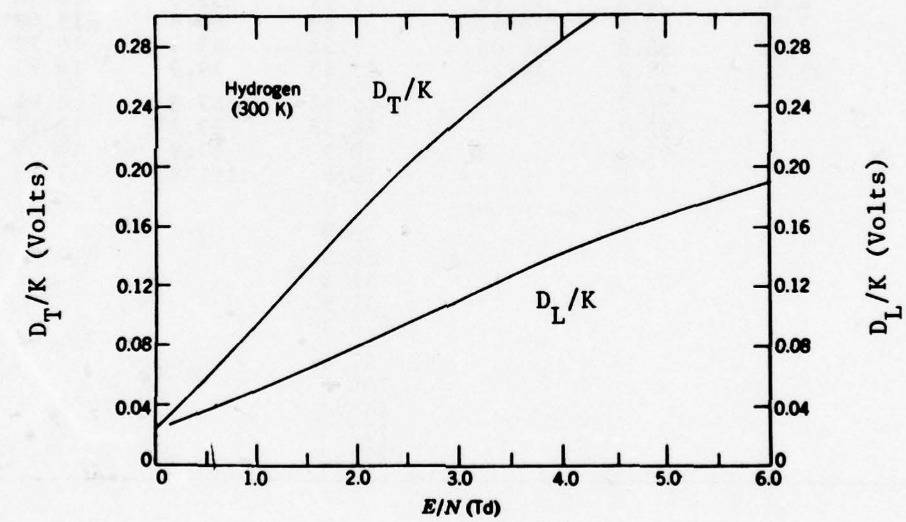
Units: E/N in Td; v_d in 10^5 cm/sec; D_T/K in 10^{-2} V; ND_T in 10^{21} $cm^{-1}sec^{-1}$

E/N	T = 77 K			T = 293 K		
	v_d	D_T/K	ND_T	v_d	D_T/K	ND_T
0.005		0.709				
0.01	0.332	0.790	2.62			
0.03	0.758	1.179	2.98	0.459	2.65	4.05
0.06	1.212	1.649	3.33	0.870	2.85	4.13
0.10	1.725	2.10	3.62	1.369	3.15	4.31
0.20	2.78	2.94	4.08	2.35	3.87	4.54
0.30	3.61	3.64	4.38	3.13	4.57	4.77
0.50	4.86	5.02	4.88	4.33	5.93	5.13
0.70	5.75	6.42	5.27	5.24	7.35	5.50
1.00	6.71	8.60	5.77	6.23	9.53	5.94
1.40	7.50	11.57	6.20	6.92	12.48	6.17
2.00	8.70	15.95	6.94	8.37	16.76	7.01
2.50	9.36	19.29	7.22	9.13	20.1	7.33
3.00	9.97	22.4	7.45	9.82	23.1	7.56
4.00	11.60	27.8	8.06	11.47	28.5	8.16
6.00	14.20	36.6	8.66	14.15	37.1	8.76
8.00	16.60	44.0	9.13	16.50	44.7	9.21
10.0	18.80	50.6	9.51	18.70	51.1	9.56
12.0	20.9	56.5	9.84	20.7	57.3	9.88
14.0	22.8			22.7	63.0	10.21
17.0	25.5			25.5	71.0	10.65
20.0	28.1			28.1	78.7	11.06
25.0	32.2			32.2	91.6	11.79
30.0				36.6	105.1	12.81
40.0				45.4	133.3	15.12
60.0				69.5	198.2	23.0
80.0				98.0	237.	29.1
100.				128.3	267.	34.2
140.				194.3	319.	44.3
200.					382.	

Reference: These data were taken from Chapter 14 of the book by L. G. H. Huxley and R. W. Crompton, The Diffusion and Drift of Electrons in Gases, Wiley, New York (1974). The original data are from a variety of sources, as referenced in Huxley and Crompton.



(a) v_d and D_T/K as a function of E/N for electrons in H_2 (from the book by Huxley and Crompton).



(b) D_T/K and D_L/K as a function of E/N for electrons in H_2 (from the book by Huxley and Crompton).

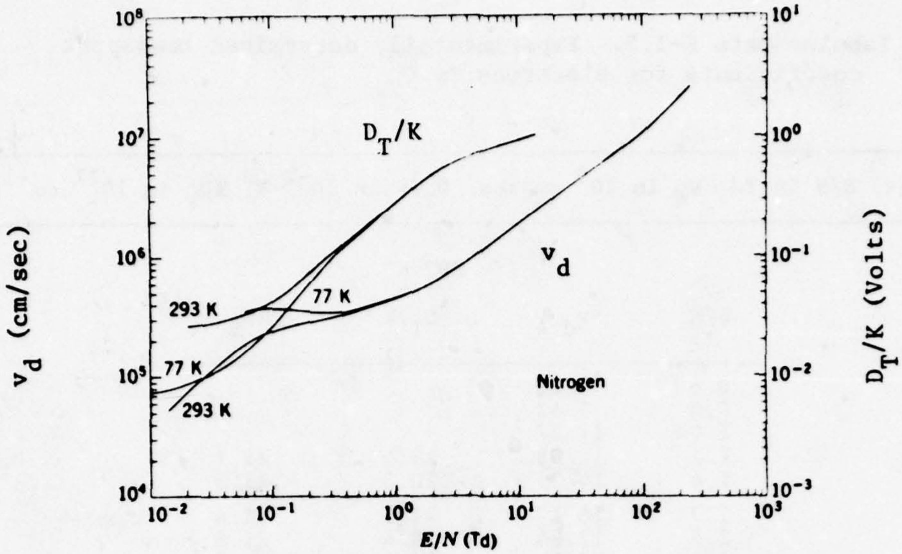
Graphical Data E-1.2. Experimentally determined transport coefficients for electrons in H_2.

Tabular E-1.3. Experimentally determined transport coefficients for electrons in N_2.

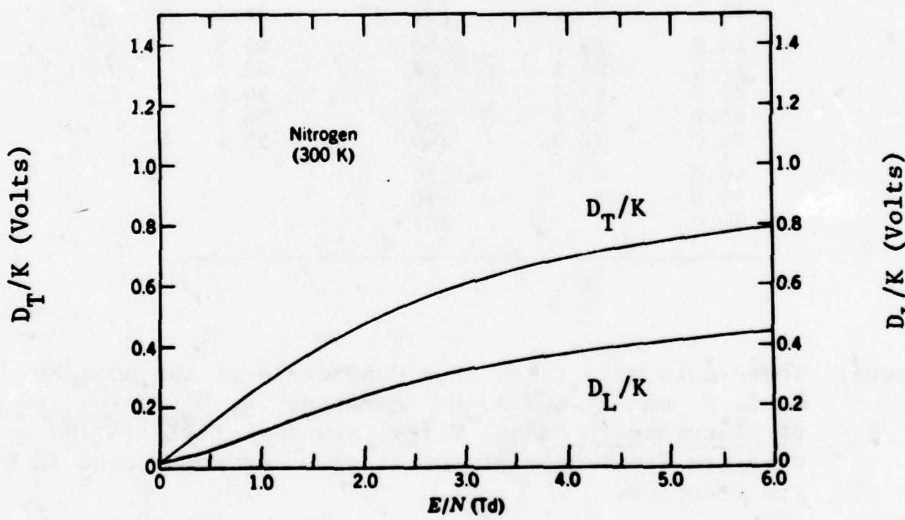
Units: E/N in Td; v_d in 10^5 cm/sec; D_T/K in 10^{-2} V; ND_T in 10^{21} $cm^{-1}sec^{-1}$

E/N	T = 77 K			T = 293 K		
	v_d	D_T/K	ND_T	v_d	D_T/K	ND_T
0.01		0.74				
0.03		1.02		1.061	2.77	9.79
0.06	3.47	1.59	9.20	1.810	3.27	9.86
0.10	3.68	2.60	9.57	2.38	4.18	9.92
0.20	3.49	5.75	10.02	2.87	7.13	10.22
0.30	3.39	9.15	10.34	3.09	10.21	10.50
0.50	3.66	14.9	10.90	3.53	15.58	11.00
0.70	4.00	19.8	11.32	3.93	20.4	11.48
1.00	4.47	27.2	12.17	4.43	27.7	12.25
1.40	5.07	36.3	13.15	5.03	36.8	13.22
2.00	6.04	47.5	14.34	5.98	48.0	14.36
2.50	6.86	54.6	14.98	6.79	55.0	14.94
3.00	7.72	60.1	15.47	7.67	60.6	15.48
4.00	9.42	68.3	16.08	9.33	69.1	16.12
6.00	12.70	79.2	16.76	12.60	79.7	16.73
8.00		86.7		15.52	87.3	16.94
10.0		92.7		18.38	93.2	17.12
12.0		97.4		20.9	97.9	17.09
14.0				23.5	101.9	17.13
17.0				27.3		
20.0				30.9		
25.0				36.5		
30.0				41.7		
40.0				51.8		
60.0				70.3		
80.0				87.4		
100.				105.1		
140.				148.0		
200.				212.		
240.				252.		

Reference: These data were taken from Chapter 14 of the book by L. G. H. Huxley and R. W. Crompton, The Diffusion and Drift of Electrons in Gases, Wiley, New York (1974). The original data are from a variety of sources, as referenced in Huxley and Crompton.



(a) v_d and D_T/K as a function of E/N for electrons in N_2 (from the book by Huxley and Crompton).



(b) D_T/K and D_L/K as a function of E/N for electrons in N_2 (from the book by Huxley and Crompton).

Graphical Data E-1.4. Experimentally determined transport coefficients for electrons in N_2.

Tabular Data E-1.5. Experimentally determined transport coefficients for electrons in O_2.

Units: E/N in Td; v_d in 10^5 cm/sec; D_T/K in 10^{-2} V; ND_T in 10^{21} $cm^{-1}sec^{-1}$

T = 293 K

E/N	v_d	D_T/K	ND_T
0.6	7.20		
0.8	9.40		
1.0	11.37		
1.2	12.98	19.5	21.1
1.4	14.35	20.8	21.3
1.7	16.17	22.5	21.4
2.0	17.84	24.4	21.8
2.5	20.1	27.0	21.7
3.0	22.0	30.0	22.0
4.0	24.4	38.8	23.7
5.0	25.7	49.2	25.3
6.0	26.6	61.0	27.0
8.0	28.7	84.8	30.5
10.0	31.4	109.	34.3
12.0	34.6	132.	38.1
14.0	38.2	156.	42.5
17.0	43.6	188.	48.2
20.0	49.4	206.	50.9
25.0	59.9	228.	54.7
30.0	72.3	244.	58.8
40.0		270.	
50.0		290.	
60.0		307	

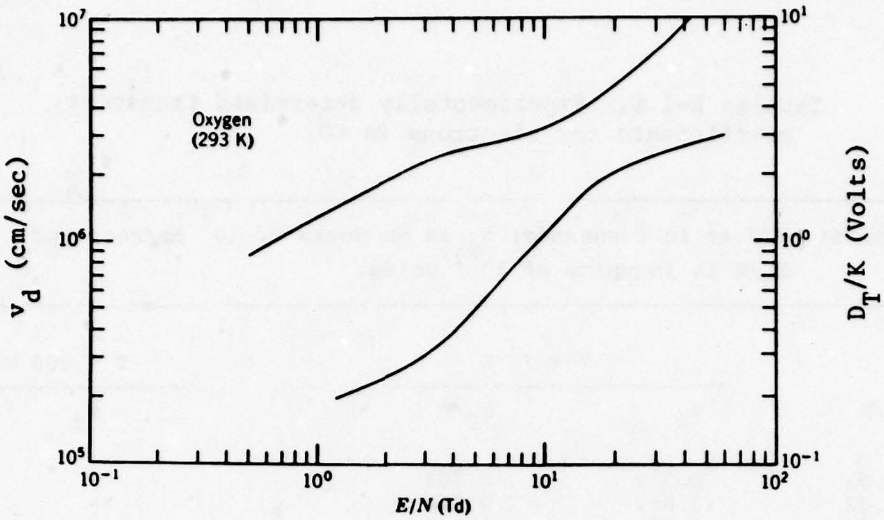
Reference: These data were taken from Chapter 14 of the bock by L. G. H. Huxley and R. W. Crompton, The Diffusion and Drift of Electrons in Gases, Wiley, New York (1974). The original data are from a variety of sources, as referenced in Huxley and Crompton.

Tabular E-1.6. Experimentally determined transport coefficients for electrons in CO.

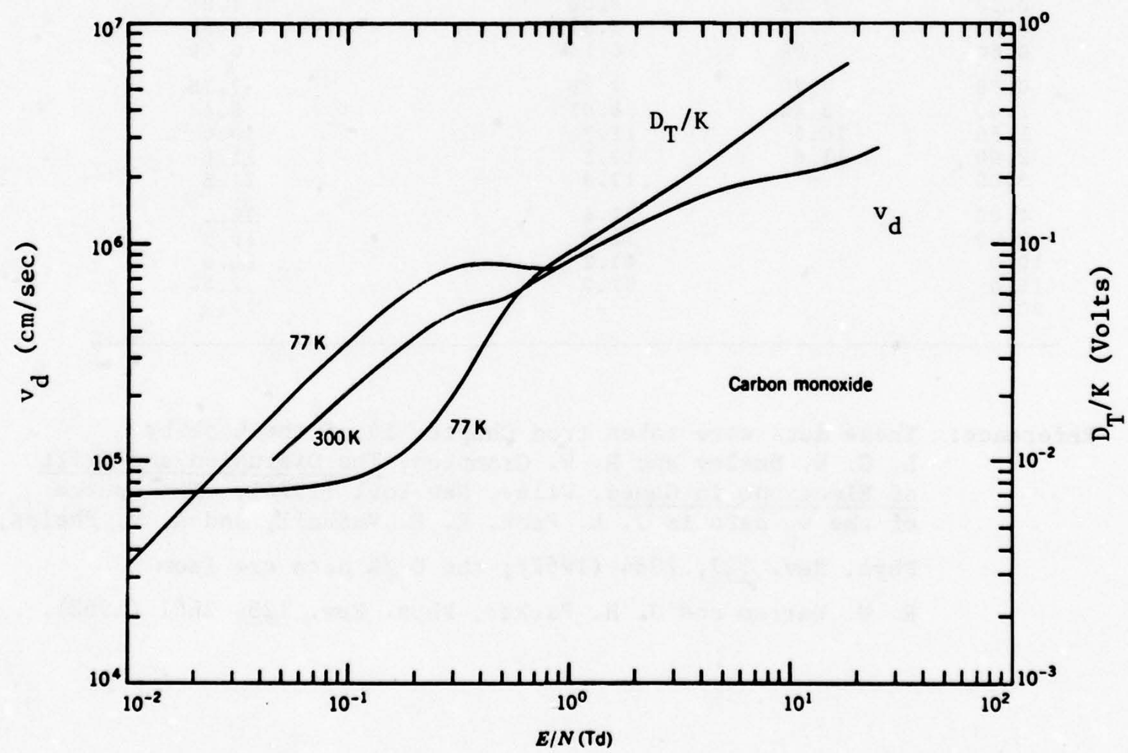
Units: E/N is in Townsends; v_d is in units of 10^5 cm/sec; and D_T/K is in units of 10^{-2} Volts.

	T = 77 K		T = 300 K
E/N	v_d	D_T/K	v_d
0.01	0.339	0.704	-
0.02	0.687	0.724	-
0.04	1.46	0.744	-
0.07	2.54	0.787	1.50
0.10	3.52	0.832	2.06
0.15	5.13	0.975	2.97
0.20	6.31	1.21	3.73
0.30	7.69	2.00	4.80
0.40	8.13	3.31	5.33
0.60	7.98	6.14	6.19
0.80	7.20	7.75	7.76
1.00	8.44	8.91	8.44
1.50	10.6	11.7	10.6
2.00	11.6	13.1	11.6
3.00	-	17.9	14.6
4.00		21.4	16.1
7.00		32.9	19.3
10.0		43.2	20.6
15.0		57.7	22.4
20.0		-	24.9

Reference: These data were taken from Chapter 14 of the book by L. G. H. Huxley and R. W. Crompton, The Diffusion and Drift of Electrons in Gases, Wiley, New York (1974). The source of the v_d data is J. L. Pack, R. E. Voshall, and A. V. Phelps, Phys. Rev. 127, 2084 (1962); the D_T/K data are from R. W. Warren and J. H. Parker, Phys. Rev. 128, 2661 (1962).



(a) v_d and D_T/K as a function of E/N for electrons in O_2 (from the book by Huxley and Crompton).



(b) v_d (at 77 and 300°K) and D_T/K (at 77°K) as a function of E/N for electrons in CO (from the book by Huxley and Crompton).

Graphical Data E-1.7. Experimentally determined transport coefficients for electrons in O_2 and CO.

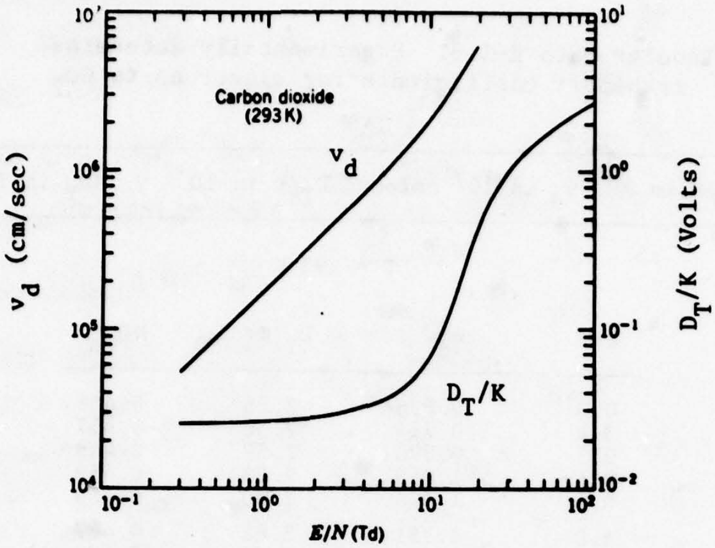
Tabular Data E-1.8. Experimentally determined transport coefficients for electrons in CO_2.

Units: E/N in Td; v_d in 10^5 cm/sec; D_T/K in 10^{-2} V; ND_T in 10^{21} $cm^{-1}sec^{-1}$

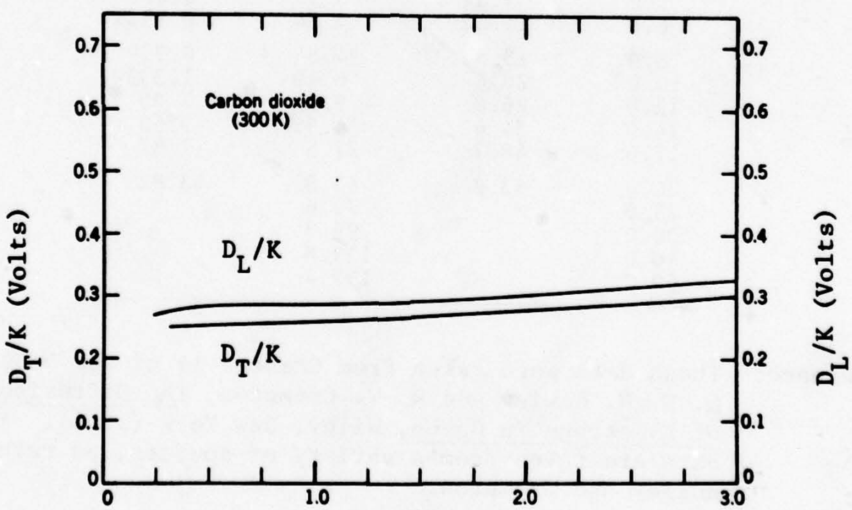
T = 293 K

E/N	v_d	D_T/K	ND_T
0.3	0.536	2.55	0.456
0.4	0.714	2.56	0.457
0.5	0.890	2.57	0.458
0.6	1.068	2.58	0.459
0.8	1.424	2.60	0.463
1.0	1.781	2.62	0.467
1.2	2.14	2.65	0.471
1.4	2.49	2.68	0.477
1.7	3.03	2.73	0.486
2.0	3.56	2.78	0.496
2.5	4.45	2.88	0.512
3.0	5.37	3.00	0.537
4.0	7.20	3.25	0.584
5.0	9.12	3.50	0.639
6.0	11.12	3.84	0.711
8.0	15.51	4.84	0.939
10.0	20.6	6.49	1.336
12.0	26.8	9.19	2.05
14.0	34.6	14.53	3.60
17.0	48.7	27.5	7.87
20.0	63.2	43.8	13.82
25.0		73.6	
30.0		99.3	
40.0		139.8	
60.0		197.4	

Reference: These data were taken from Chapter 14 of the book by L. G. H. Huxley and R. W. Crompton, The Diffusion and Drift of Electrons in Gases, Wiley, New York (1974). The original data are taken from a variety of sources, as referenced in Huxley and Crompton.



(a) v_d and D_T/K as a function of E/N for electrons in CO_2 (from the book by Huxley and Crompton).



(b) D_T/K and D_L/K as a function of E/N (at low E/N) for electrons in CO_2 (from the book by Huxley and Crompton).

Graphical Data E-1.9. Experimentally determined transport coefficients for electrons in CO_2.

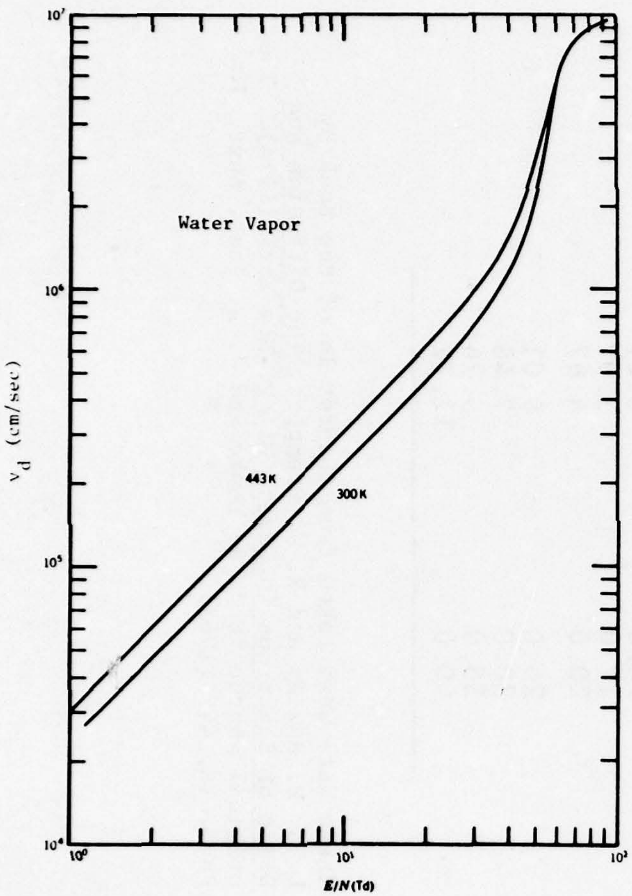
Tabular Data E-1.10. Experimentally determined drift velocities for electrons in H_2O.

Units: E/N is in Td; v_d is in 10^5 cm/sec

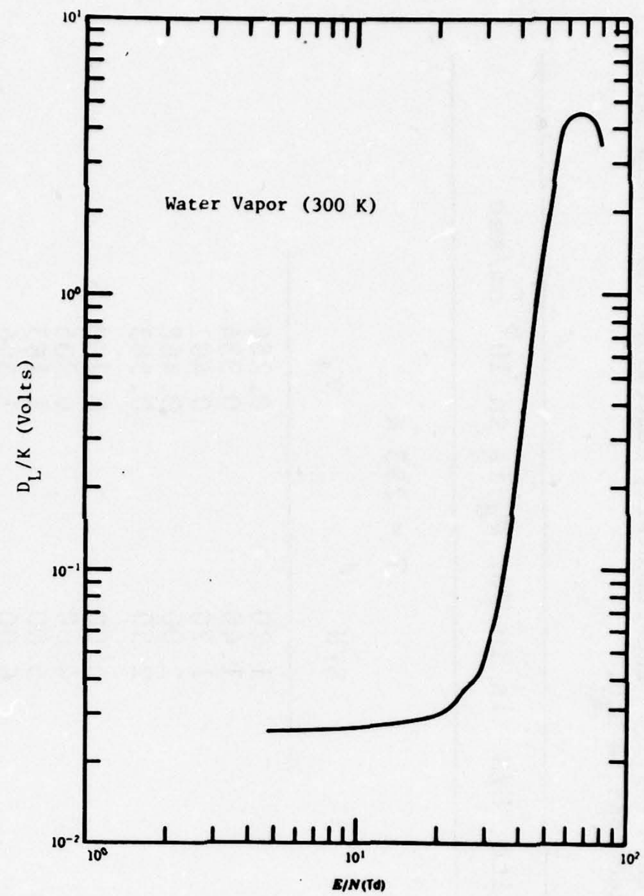
T = 293 K

E/N	v_d
1.20	0.286
1.40	0.334
1.70	0.401
2.00	0.468
2.50	0.583
3.00	0.703
4.00	0.935
5.00	1.165
6.00	1.396
8.00	1.869
10.0	2.34
12.0	2.80
14.0	3.27
17.0	3.97
20.0	4.67
25.0	6.01
30.0	7.46
35.0	9.26
40.0	11.72

Reference: These data were taken from Chapter 14 of the book by L. G. H. Huxley and R. W. Crompton, The Diffusion and Drift of Electrons in Gases, Wiley, New York (1974). The original source is J. J. Lowke and J. A. Rees, Aust. J. Phys. 16, 447 (1963).



(a) v_d as a function of E/N for electrons in H_2O (from the book by Huxley and Crompton).



(b) D_L/K as a function of E/N for electrons in H_2O (from the book by Huxley and Crompton).

Graphical Data E-1.11. Experimentally determined drift velocities and diffusion coefficients for electrons in H_2O.

Tabular Data E-1.12. Calculated transport properties of electrons in a CO_2:N_2:He gas mixture in the proportion 1:0.25:3.

Units: E/N in Td; v_d in 10^5 cm/sec; D_T/K and D_L/K in 10^{-1} V; α/N and a/N in cm^2

E/N	v_d	D_T/K	D_L/K	α/N	a/N
0.1	0.607	0.256	0.257	-	-
0.3	1.98	0.274	0.299	-	-
1.0	6.28	0.342	0.355	-	-
3.0	17.0	0.616	0.544	-	-
5.0	27.3	1.11	0.991	-	-
7.0	35.9	2.08	1.47	-	-
10.0	43.7	4.13	2.23	2.68E-30	5.93E-24
15.0	51.7	7.27	3.68	-	-
20.0	58.3	9.93	5.03	1.37E-22	8.11E-21
30.0	69.8	15.2	8.09	1.88E-20	4.54E-20
50.0	93.3	24.7	17.3	6.12E-19	9.97E-20
100.	150.	41.9	30.2	7.65E-18	1.02E-19
300.	331.	88.7	63.2	6.80E-17	3.80E-20

Reference: These data were taken from tabulations kindly provided by the authors of the paper: J. J. Lowke, A. V. Phelps, and B. W. Irwin, J. Appl. Phys. 44, 4664 (1973).

Tabular Data E-1.13. Calculated transport properties of electrons in a CO_2:N_2:He gas mixture in the proportion 1:7:30.

Units: E/N in Td; v_d in 10^5 cm/sec; D_T/K and D_L/K in 10^{-1} V; α/N and a/N in cm^2

E/N	v_d	D_T/K	D_L/K	α/N	a/N
0.1	1.75	0.294	0.274	-	-
0.3	4.61	0.405	0.343	-	-
1.0	10.5	0.883	0.540	-	-
3.0	15.8	3.28	1.79	-	-
5.0	18.5	5.90	2.70	-	-
10.0	28.4	8.61	4.49	-	2.90E-23
15.0	39.0	9.83	-	4.20E-24	-
20.0	47.9	11.4	6.57	2.87E-22	1.86E-21
30.0	64.8	15.3	10.3	2.10E-20	5.87E-21
40.0	80.2	20.0	-	1.77E-19	-
50.0	95.1	24.5	-	6.10E-19	1.07E-20
60.0	110.	28.8	-	1.42E-18	-
100.	166.	43.8	36.5	7.99E-18	9.60E-21
300.	407.	99.5	82.3	7.03E-17	3.00E-21

Reference: These data were taken from tabulations kindly provided by the authors of the paper: J. J. Lowke, A. V. Phelps, and B. W. Irwin, J. Appl. Phys. 44, 4664 (1973).

Tabular Data E-1.14. Calculated transport properties of electrons in a CO_2:N_2:He gas mixture in the proportion 1:1:8.

Units: E/N in Td; v_d in 10^5 cm/sec; D_T/K and D_L/K in 10^{-1} V; α/N and a/N in cm^2

E/N	v_d	D_T/K	D_L/K	α/N	a/N
0.1	1.05	0.266	0.261	-	-
0.3	3.21	0.304	0.307	-	-
1.0	9.37	0.462	0.405	-	-
3.0	21.5	1.18	0.742	-	-
5.0	27.7	2.65	-	-	-
10.0	35.5	6.62	3.31	3.35E-27	6.17E-23
20.0	52.2	11.5	6.38	1.22E-21	9.59E-21
30.0	66.7	16.9	9.54	5.71E-20	3.07E-20
50.0	-	-	-	-	4.79E-20
70.0	-	-	-	-	4.75E-20
100.	162.	46.5	33.3	8.54E-18	3.97E-20
300.	389.	101.	77.2	6.63E-27	1.18E-20

Reference: These data were taken from tabulations kindly provided by the authors of the paper: J. J. Lowke, A. V. Phelps, and B. W. Irwin, J. Appl. Phys. 44, 4664 (1973).

Tabular Data E-1.15. Calculated transport properties of electrons in a CO_2:N_2:He gas mixture in the proportion 1:2:3.

Units: E/N in Td; v_d in 10^5 cm/sec; D_T/K and D_L/K in 10^{-1} V; α/N and a/N in cm^2

E/N	v_d	D_T/K	D_L/K	α/N	a/N
0.1	0.782	0.256	0.256	-	-
0.3	2.50	0.282	0.294	-	-
1.0	7.63	0.380	0.366	-	-
3.0	19.4	0.81	0.61	-	-
6.0	30.9	2.05	1.14	-	-
10.0	37.2	4.73	2.11	-	2.13E-26
20.0	51.0	8.60	3.97	9.22E-26	2.60E-22
30.0	65.0	10.8	5.25	1.22E-22	4.25E-21
50.0	89.0	16.0	9.96	3.60E-20	2.77E-20
70.0	112.	21.7	15.4	3.70E-19	4.67E-20
100.	144.	29.4	22.0	2.04E-18	5.59E-20
300.	308.	69.6	48.7	4.00E-17	3.27E-20

Reference: These data were taken from tabulations kindly provided by the authors of the paper: J. J. Lowke, A. V. Phelps, and B. W. Irwin, J. Appl. Phys. 44, 4664 (1973).

Tabular Data E-1.16. First ionization coefficient for electrons in H_2 and CO and effective ionization coefficient for electrons in O_2 and CO_2.

Units: E/N is in units of 10^{-15} V-cm^2 (i.e. 10^2 Townsends). α/N is in units of cm^2, as is (α-a)/N.

E/N	α/N		(α-a)/N	
	H_2	CO	O_2	CO_2
1.00	-	-	1.80E-20	3.96E-19
1.20	-	-	1.27E-19	1.49E-18
1.50	-	-	4.26E-19	4.02E-18
2.00	-	-	1.15E-18	1.08E-17
3.00	-	-	2.88E-18	3.04E-17
4.00	-	-	4.65E-18	5.08E-17
5.00	-	-	6.02E-18	8.20E-17
6.00	-	-	7.51E-18	1.06E-16
8.00	-	-	9.71E-18	1.48E-16
10.0	-	-	-	1.84E-16
12.0	-	-	-	2.13E-16
15.0	-	-	-	2.47E-16
20.0	-	-	-	2.97E-16
30.0	-	-	-	3.84E-16
40.0	-	-	-	4.14E-16
50.0	1.95E-20	-	-	4.29E-16
60.0	1.14E-19	-	-	4.29E-16
70.0	3.69E-19	-	-	-
80.0	8.36E-19	-	-	4.29E-16
100.	2.39E-18	-	-	-
120.	4.64E-18	8.80E-20	-	-
150.	1.00E-17	4.08E-19	-	-
200.	1.94E-17	1.90E-18	-	-
250.	2.78E-17	4.39E-18	-	-
300.	3.78E-17	-	-	-
350.	4.64E-17	-	-	-

Reference: These data were taken from the book by J. M. Meek and J. D. Craggs, Electrical Breakdown of Gases, Wiley, New York (1976).

Tabular Data E-1.17. First ionization coefficient for electrons in He, N_2, and CO_2.

Units: E/N is in units of Townsends (10^{-17} V-cm^2). α/N is in units of cm^2.

E/N	α/N (in He)	α/N (in N_2)	α/N (in CO_2)
17.5	2.30E-19	-	-
20.0	3.99E-19	-	-
25.0	8.59E-19	-	-
30.0	1.43E-18	-	-
35.0	-	-	2.49E-23
40.0	2.72E-18	-	1.75E-22
50.0	3.99E-18	3.20E-23	2.68E-21
60.0	5.15E-18	4.24E-22	1.65E-20
70.0	6.19E-18	2.69E-21	6.07E-20
80.0	7.10E-18	1.07E-20	1.61E-19
90.0	7.90E-18	3.15E-20	3.43E-19
100.	8.60E-18	7.46E-20	6.30E-19
120.	9.77E-18	2.72E-19	1.56E-18
140.	1.07E-17	6.83E-19	3.00E-18
160.	1.15E-17	1.37E-18	4.88E-18
180.	1.21E-17	2.34E-18	7.13E-18
200.	1.26E-17	3.60E-18	9.65E-18
250.	1.36E-17	7.82E-18	1.67E-17
300.	1.43E-17	1.31E-17	2.40E-17
350.	1.49E-17	1.90E-17	3.11E-17
400.	1.53E-17	2.50E-17	3.78E-17

Reference: These data were provided by Dr. A. V. Phelps.

Tabular Data E-1.18. Transport properties of electrons in CCl_2F_2; ionization coefficient for electrons in O_2.

Transport properties of electrons in CCl_2F_2 at T = 293°K

Units: E/p_{20} is in units of V/cm-torr, the pressure having been normalized to 293 K. v_d is in units of 10^7 cm/sec, and D_T/K is in units of Volts.

E/p_{20}	v_d	D_T/K
110.		3.62
120.	1.83	3.64
130.	1.95	3.66
140.	2.07	3.67
150.	2.14	3.70
160.	2.18	3.72
170.	2.25	3.75
180.	2.33	3.79
190.	2.42	3.83
200.	2.52	3.88
210.	2.65	3.91

Reference: These data were taken from M. S. Naidu and A. N. Prasad, J. Phys. D. 2, 1431 (1969).

First Ionization Coefficient for Electrons in O_2

Units: E/N is in Townsends, α/N is in cm^2.

E/N	α/N
85.	4.21E-19
90.	5.90E-19
100.	1.05E-18
110.	1.55E-18
120.	2.15E-18
130.	2.94E-18
140.	3.73E-18
150.	4.70E-18
160.	5.58E-18
170.	6.58E-18
180.	7.55E-18

Reference: These data were taken from D. A. Price, J. Lucas, and J. L. Moruzzi, J. Phys. D. 5, 1249 (1972).

Tabular Data E-1.19. Drift velocities of electrons in CF_4, C_2F_6, C_3F_8, and C_4F_{10}.

Units: E/p_{20} is in units of V/cm-torr, where the pressure has been normalized to 293 K. v_d is in units of 10^7 cm/sec.

Note: E/p_{20} may be converted to E/N in Townsends by use of the equation

$$E/N\ (\text{Td}) = 0.010354 \times T \times E/p$$

where T is the gas temperature (293 K in this instance).

E/p_{20}	v_d in CF_4	v_d in C_2F_6	v_d in C_3F_8	v_d in C_4F_{10}
40.0	1.51			
50.0	1.75			
60.0	2.04			
70.0	2.37			
80.0	2.71			
90.0	3.08	1.77	1.54	1.36
100.		1.95	1.63	1.42
110.		2.12	1.72	1.47
120.		2.32	1.81	1.53
130.		2.50	1.92	1.58
140.		2.71	2.01	1.62
150.		2.89	2.10	1.67
160.		3.10	2.17	1.72
170.		3.32	2.23	1.78
180.		3.50	2.29	1.83
190.		3.71	2.34	1.90
200.			2.39	

Reference: These data were taken from M. S. Naidu and A. N. Prasad, J. Phys. D. 5, 983 (1972).

Tabular Data E-1.20. D_T/K for electrons in CF_4, C_2F_6, C_3F_8, and C_4F_{10}.

Units: E/p_{20} is in units of V/cm-torr, where the pressure has been normalized to 293 K. D_T/K is in units of Volts.

Note: E/p_{20} may be converted to E/N in Townsends by use of the equation

$$E/N\ (\text{Td}) = 0.010354 \times T \times E/p$$

where T is the gas temperature (293 K in this instance).

E/p_{20}	D_T/K (CF_4)	D_T/K (C_2F_6)	D_T/K (C_3F_8)	D_T/K (C_4F_{10})
40.0	4.32			
50.0	4.59			
60.0	4.84			
70.0	5.02			
80.0	5.18			
90.0	5.29	3.56	2.93	2.66
100.	5.41	3.96	3.18	2.86
110.	5.51	4.21	3.42	3.05
120.		4.41	3.62	3.21
130.		4.56	3.83	3.37
140.		4.68	4.00	3.50
150.		4.77	4.16	3.63
160.		4.87	4.29	3.76
170.		4.97	4.39	3.87
180.		5.06	4.47	3.96
190.		5.12	4.55	
200.		5.19	4.61	
210.			4.68	

Reference: These data were taken from M. S. Naidu and A. N. Prasad, J. Phys. D 5, 983 (1972).

Tabular Data E-1.21. Attachment and ionization coefficients for electrons in CF_4 and C_2F_6.

Units: E/p_{20} is in units of V/cm-torr, the pressure having been normalized to 293 K. α/p_{20} and a/p_{20} are in units of $cm^{-1}torr^{-1}$.

	CF_4		C_2F_6	
E/p_{20}	α/p_{20}	a/p_{20}	α/p_{20}	a/p_{20}
40.0	0.095	0.166		
50.0	0.253	0.137		
60.0	0.436	0.117		
70.0	0.638	0.101		
80.0	0.853	0.084		
90.0	1.042	0.071		0.497
100.	1.232	0.060	0.638	0.442
110.	1.427	0.046	0.821	0.384
120.			1.004	0.324
130.			1.232	0.267
140.			1.415	0.205
150.			1.592	0.150
160.			1.787	0.095
170.			1.983	0.033
180.			2.179	
190.			2.362	
200.			2.539	

Reference: These data were taken from M. S. Naidu and A. N. Prasad, J. Phys. D 5, 983 (1972).

Tabular Data E-1.22. Transport properties of electrons in SF_6.

Units: E/p_{20} is in units of V/cm-torr, the pressure having been normalized to 293 K. v_d is in units of 10^7 cm/sec; D_T/K is in units of Volts; $(\alpha-a)/p_{20}$ is in units of cm^{-1} $torr^{-1}$.

E/p_{20}	v_d	D_T/K	$(\alpha-a)/p_{20}$
80.0			-0.951
90.0			-0.696
100.			-0.453
110.			-0.193
120.	2.04	5.05	+0.045
130.	2.29	5.13	0.327
140.	2.53	5.21	0.614
150.	2.78	5.29	0.914
160.	2.96	5.38	1.204
170.	3.13	5.46	-
180.	3.28	5.51	
190.	3.45	5.56	
200.	3.65	5.61	
210.		5.65	

Reference: The data for v_d and D_T/K were taken from M. S. Naidu and A. N. Prasad, J. Phys. D 5, 1090 (1972). The values of $(\alpha-a)p_{20}$ were taken from J. M. Meeks and J. D. Craggs, Electrical Breakdown of Gases, Wiley, New York (1977). The data originally appeared in M. S. Bhalla and J. D. Craggs, Proc. Phys. Soc. 80,151 (1962).

Tabular Data E-1.23. Drift velocities of electrons in NH_3 and N_2O gases.

Units: E/p_{27} is in units of V/cm-torr, the pressure having been normalized to a temperature of 300 K. v_d is in units of 10^5 cm/sec. Note that E/p_{27} may be converted to E/N in Townsends by use of the equation

$$E/N\ (Td) = 0.010354 \times T \times E/p$$

where T is the gas temperature (300 K in this instance)

E/p_{27}	v_d (in NH_3)	v_d (in N_2O)
0.01	0.014	-
0.02	0.027	-
0.04	0.054	0.827
0.06	0.081	1.19
0.08	0.104	1.57
0.10	0.135	2.02
0.20	0.259	3.88
0.40	0.516	8.46
0.60	0.828	14.1
0.80	1.03	19.9
1.00	1.33	26.1
2.00	2.46	52.0
4.00	5.28	86.5
6.00	9.61	102.
8.00	15.1	-
10.0	28.6	-
20.0	102.	-

Reference: These data were taken from J. L. Pack, R. E. Voshall, and A. V. Phelps, Phys. Rev. 127, 2084 (1962).

E-2. TRANSPORT PROPERTIES OF IONS

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E-2. TRANSPORT PROPERTIES OF IONS

Definitions and Relationships

$\vec{v}_d$ = Drift velocity of ion = average velocity of drift of ion along field lines in a gas exposed to a constant, uniform electric field $\vec{E}$. v_d is usually expressed in cm/sec.

K = Mobility of ion, defined by the equation $\vec{v}_d = K\,\vec{E}$. K is usually expressed in cm^2/V-sec.

K_o = Reduced mobility of ion = mobility of ion reduced to S.T.P., defined by the equation

$$K_o = \frac{P}{760}\,\frac{273.16}{T}\,K,$$

where p is the gas pressure in torr and T is the gas temperature in degrees Kelvin at which K was measured.

P_o = Reduced pressure = $\frac{273.16}{T}\,P$.

E/N = Ionic energy parameter = ratio of electric field intensity to gas number density. E/N is usually expressed in units of (volts/cm) / ($1/cm^3$) = $V - cm^2$.

$K_o(0)$ = Zero-field reduced mobility = K_o in the limit $E/N \to 0$.

Td = Unit of E/N, the "Townsend" = 10^{-17} $V - cm^2$.

v_d = $0.0269 \times (E/N) \times K_o$, where v_d is in 10^4 cm/sec, E/N is in Td, and K_o is in $cm^2/V - sec$.

$$\overleftrightarrow{D} = \begin{vmatrix} D_T & 0 & 0 \\ 0 & D_T & 0 \\ 0 & 0 & D_L \end{vmatrix} = \text{ionic diffusion tensor.}$$

D_L = (Scalar) longitudinal diffusion coefficient = coefficient of diffusion along electric field.

D_T = (Scalar) transverse diffusion coefficient = coefficient of diffusion tranverse to electric field.

In the limit $E/N \to 0$, $D_L = D_T = D$, the scaler diffusion coefficient.

For a particular ionic species in a given gas at a given temperature, v_d, NK, ND_L, ND_T, and the average ionic energy are functions of E/N alone.

General References

H. W. Ellis, R. Y. Pai, I. R. Gatland, E. W. McDaniel, R. Wernlund, and M. J. Cohen, "Ion Identity and Transport Properties in CO_2 Over a Wide Pressure Range," J. Chem. Phys. 64, 3935 (1976).

H. W. Ellis, F. L. Eisele, and E. W. McDaniel, "Temperature Dependent Mobilities of Negative Ions in N_2 and O_2," Jour. Chem. Phys. 69, 4710 (1978).

I. R. Gatland, "Analysis for Ion Drift Tube Experiments," in E. W. McDaniel and M. R. C. McDowell (Eds.), "Case Studies in Atomic Physics," 4, 371, North-Holland, Amsterdam (1975).

I. R. Gatland, W. F. Morrison, H. W. Ellis, M. G. Thackston, E. W. McDaniel, M. H. Alexander, L. A. Viehland, and E. A. Mason, "The Li^+-He Interaction Potential," Jour. Chem. Phys. 66, 5121 (1977).

I. R. Gatland, M. G. Thackston, W. M. Pope, F. L. Eisele, H. W. Ellis, and E. W. McDaniel, "Mobilities and Interaction Potentials for Cs^+-Ar, Cs^+-Kr, and Cs^+-Xe," Jour. Chem. Phys. 68, 2775 (1978).

I. R. Gatland, D. R. Lamm, M. G. Thackston, W. M. Pope, F. L. Eisele, H. W. Ellis, and E. W. McDaniel, "Mobilities and Interaction Potentials for Rb^+-Ar, Rb^+-Kr, and Rb^+-Xe," Jour. Chem. Phys. 69, 4951 (1978).

S. L. Lin and J. N. Bardsley, "Monte Carlo Simulation of Ion Motion in Drift Tubes," Jour. Chem. Phys. 66, 435 (1977).

S. L. Lin and E. A. Mason, "Influence of Resonant Charge Transfer on Ion Mobility," J. Phys. B. 12, 783 (1979).

S. L. Lin, L. A. Viehland, and E. A. Mason, "Three-Temperature Theory of Gaseous Ion Transport," Chem. Phys. 37, 411 (1979).

H. S. W. Massey, "Electronic and Ionic Impact Phenomena," Vol. 3, Clarendon, Oxford (1971).

H. S. W. Massey, "Negative Ions," Cambridge University Press, New York (1976).

E. W. McDaniel and E. A. Mason, "The Mobility and Diffusion of Ions in Gases," Wiley, New York (1973).

L. A. Viehland and E. A. Mason, "Gaseous Ion Mobility in Electric Fields of Arbitrary Strength," Annals of Physics 91, 499 (1975).

L. A. Viehland and E. A. Mason, "On the Choice of Buffer Gas Mixtures for Drift-Tube Studies of Ion-Neutral Reactions", Jour. Chem. Phys. 70, 2262 (1979).

L. A. Viehland and S. L. Lin, "Application of the Three-Temperature Theory of Gaseous Ion Transport," Chem. Phys., in press.

L. A. Viehland and E. A. Mason, "Gaseous Ion Mobility and Diffusion in Electric Fields of Arbitrary Strength," Annals of Physics 110, 287-328 (1978).

L. A. Viehland, E. A. Mason, W. F. Morrison, and M. R. Flannery, "Tables of Transport Collision Integrals for (n,6,4) Ion-Neutral Potentials," Atomic Data and Nuclear Data Tables 16, 495 (1975).

Data Compilations

H. W. Ellis, R. Y. Pai, E. W. McDaniel, E. A. Mason, and L. A. Viehland, "Transport Properties of Gaseous Ions Over a Wide Energy Range," Atomic Data and Nuclear Data Tables 17, 177-210 (1976).

ABSTRACT

A compilation of experimental data is presented for the mobilities of mass-identified ions in neutral gases at room temperature as a function of the ionic energy parameter E/N, the ratio of electric field strength to neutral gas number density. The literature has been covered to February 1976. In addition, a recently developed theory of gaseous ion mobility is used to compute, for each ion-gas combination, the zero-field reduced mobility as a function of the common ion-gas temperature. Finally, it is shown how the tabulated data can be used to estimate the ionic diffusion coefficients and to obtain information about the ion-neutral interaction potential.

H. W. Ellis, E. W. McDaniel, D. L. Albritton, L. A. Viehland, S. L. Lin, and E. A. Mason, "Transport Properties of Gaseous Ions Over a Wide Energy Range - Part II", Atomic Data and Nuclear Data Tables 22, 179-217 (1978).

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COMPILATION OF DATA RELEVANT TO NUCLEAR PUMPED LASERS. VOLUME V--ETC(U)
FEB 79 E W MCDANIEL, M R FLANNERY, E W THOMAS

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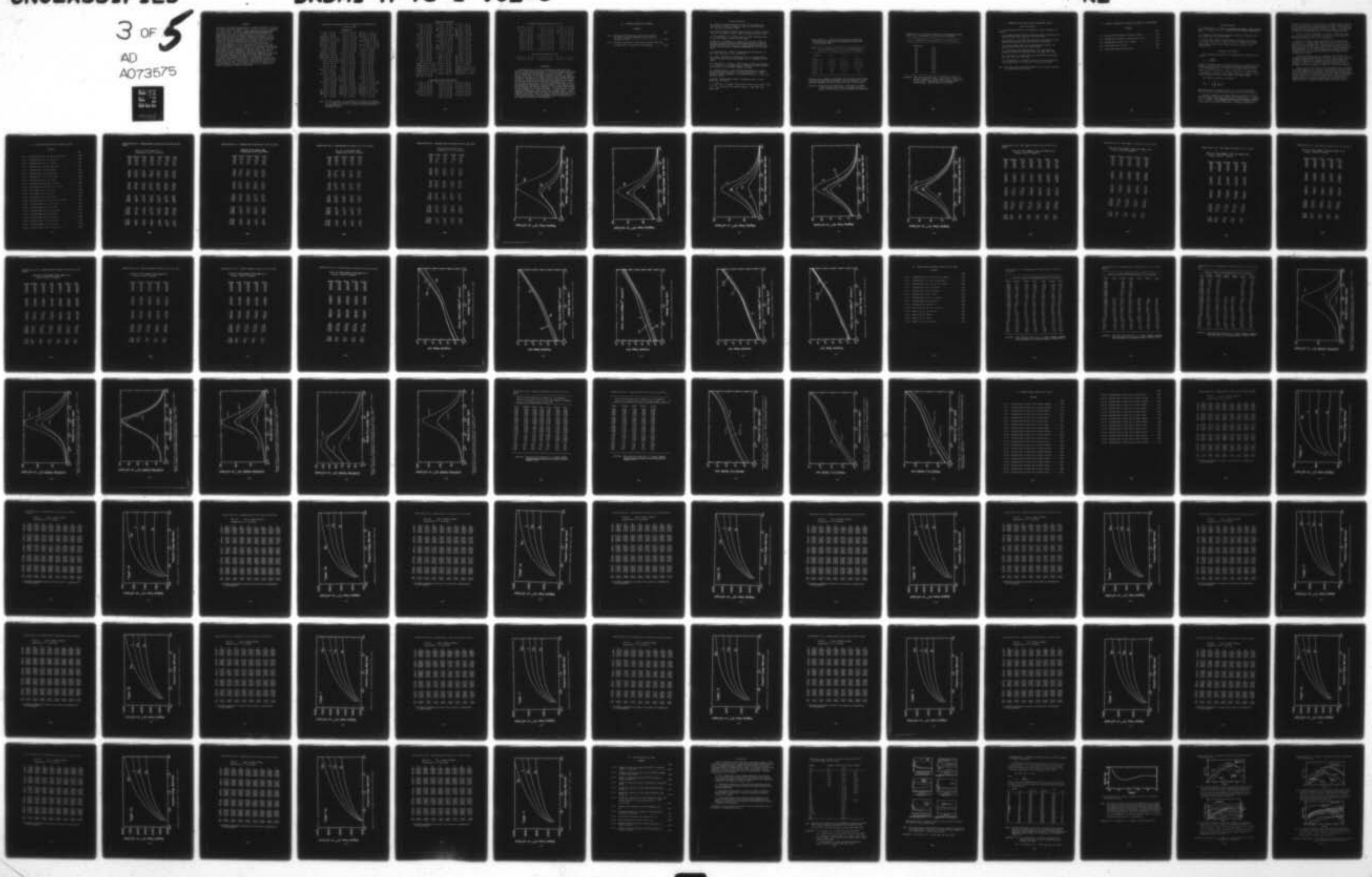


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ABSTRACT

This paper is an update and extension of "Transport Properties of Gaseous Ions Over a Wide Energy Range", by H. W. Ellis, R. Y. Pai, E. W. McDaniel, E. A. Mason, and L. A. Viehland, Atomic Data and Nuclear Data Tables 17, 177-210 (1976). The previous paper presented a compilation of experimental ionic mobility data available in February, 1976. The present article updates the mobility compilation to August, 1978 and also presents data on ionic diffusion coefficients obtained from the time of the first good measurements up to August, 1978. (Both longitudinal and transverse diffusion coefficients are included). The criteria for selection of the mobility and diffusion data were: (1) the measurements must cover a reasonably wide range of E/N, the ionic energy parameter, (2) the identity of the ions must have been well established, and (3) the accuracy of the data must be good. The mobility and diffusion data are tabulated as functions of E/N. The theory of ionic mobility recently developed by Viehland and Mason is used to calculate zero-field mobilities for each ion-gas combination as functions of an effective common ion-gas temperature which ranges from 300°K up to thousands of degrees, typically. The compilation of data is preceded by a discussion of the theory of ion transport in gases which serves to put the data compilation into perspective and show how it can be effectively utilized. The effects of inelastic collisions are also briefly discussed. The use of mobility data to test or generate ion-neutral interaction potentials is described.

References to Experimental Ionic Transport Data Published Before August 1, 1978*

Mobilities (K)

Ar^+ in Ar. I - pg. 196
in He. I - pg. 185
Ar^{2+} in Ar. I - pg. 196
$Ar^{2+}(^1D)$ in Ar. II - pg. 195
$Ar^{2+}(^3P)$ in Ar. II - pg. 195
Ar_2^+ in Ar. I - pg. 198
ArH^+ in He. I - pg. 187
Br^- in Ar. II - pg. 194
in He. II - pg. 190
C^+ in CO. I - pg. 208
CH_5^+ in He. I - pg. 190
$C_2H_2^-$ in He. I - pg. 192
$CH_3O_2^+$ in He. I - pg. 190
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COH^+ in Ar. I - pg. 198
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D^+ in D_2. I - pg. 202
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D_3^+ in D_2. I - pg. 202
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I^- in Ar. II - pg. 194
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K^+ in Ar. I - pg. 197
in CH_4. II - pg. 204
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Kr_2^+ in Kr. I - pg. 200
Kr^{2+}(A) in Kr. II - pg. 197
Kr^{2+}(B) in Kr. II - pg. 197
Li^+ in Ar. I - pg. 196
in D_2. I - pg. 202

Note: *I refers to Ellis, et al., ADNDT <u>17</u>, 177 (1976); II to Ellis, et. al., ADNDT <u>22</u>, 179 (1978). Data on many ion-gas combinations are presented on pgs. 737 - 748 of Vol. II and in the book by McDaniel and Mason.

Mobilities (K) (continued)

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in He. I - pg. 183
in N_2. II - pg. 200
in Ne. I - pg. 194
in O_2. II - pg. 203
N^+ in N_2. I - pg. 204
in He. I - pg. 184
N_2^+ in He. I - pg. 186
in N_2. I - pg. 202
N_3^+ in N_2. I - pg. 204
N_4^+ in N_2. II - pg. 202
Na^+ in Ar. I - pg. 196
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N_2O^+ in N_2. II - pg. 202
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NO_2^- in He. I - pg. 192
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O^+ in Ar. I - pg. 197
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O^- in CO_2. I - pg. 209
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O_2^+ in Ar. I - pg. 198
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SF_6^- in He. I - pg. 193
SO_3^- in He. I - pg. 193
SO_2F^- in He. I - pg. 192
U^+ in He. I - pg. 185
Xe^+ in He. II- pg. 187
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$Xe^+(^2P_{3/2})$ in Xe. II - pg. 199
Xe^{2+}(A) in Xe. II - pg. 199
Xe^{2+}(B) in Xe. II - pg. 199

Longitudinal Diffusion Coefficients (D_L)

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in Kr. II - pg. 209
in Ne. II - pg. 207
in Xe. II - pg. 210
CO^+ in CO. II - pg. 214
Cs^+ in Ar. II - pg. 208
in CO. II - pg. 214
Cs^+ in CO_2. II - pg. 215
in H_2. II - pg. 211
in He. II - pg. 206
in Kr. II - pg. 209
in N_2. II - pg. 212
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in Xe. II - pg. 210
D^+ in D_2. II - pg. 211
D^- in D_2. II - pg. 212
D_3^+ in D_2. II - pg. 212
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H^+ in H_2. II - pg. 210
H^- in H_2. II - pg. 211

Longitudinal Diffusion Coefficients (D_L) (continued)

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K^+ in Ar. II - pg. 208	in H_2. II - pg. 210	O_2^+ in O_2. II - pg. 213
in CO. II - pg. 214	in He. II - pg. 206	O_2^- in O_2. II - pg. 214
in CO_2. II - pg. 215	in Ne. II - pg. 206	Rb^+ in Ar. II - pg. 208
in H_2. II - pg. 211	N^+ in N_2. II - pg. 212	in CO_2. II - pg. 215
in He. II - pg. 206	N_2^+ in N_2. II - pg. 213	in H_2. II - pg. 211
in Kr. II - pg. 208	Na^+ in Ar. II - pg. 208	in He. II - pg. 206
in N_2. II - pg. 212	in CO_2. II - pg. 215	in Kr. II - pg. 209
in Ne. II - pg. 207	in H_2. II - pg. 210	in N_2. II - pg. 212
in NO. II - pg. 214	in He. II - pg. 206	in Ne. II - pg. 207
in O_2. II - pg. 213	in Ne. II - pg. 207	in O_2. II - pg. 213
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Transverse Diffusion Coefficients (D_T)

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K^+ in H_2. II - pg. 216	N^+ in N_2. II - pg. 216	O_2^+ in O_2. II - pg. 216

Data Needed

Practically all of the data on the systems listed above were obtained at gas pressures well below 1 Torr, and ion-molecule reactions did not complicate the measurements or vitiate the results. The data are for single ionic species whose identities are known. At higher pressures, the nature of the change carriers usually changes repeatedly (because of ion-molecule reactions) during the motion through the gas. In addition, complex ions of unexpected types frequently are produced from the simple ions formed in the primary ionization events. Hence, the greatest need in the area of ionic transport would appear to be for data showing the identities of the ions present in high pressure gases and gas mixtures, the relative abundances of the various ionic species, and the mobilities of the charge carriers. By "high pressure", we mean pressures ranging from 1 Torr to the highest possible value. In many experiments of the kind advocated here, the measured mobilities will be "apparent mobilities", which are averages of the true mobilities of the various species present. The measurements should be conducted over a wide range of gas pressure and temperature.

E-3. TRANSPORT PROPERTIES OF NEUTRALS

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E-3.1. Diffusion coefficients and two-body and three-body destruction rates for metastable rare gas atoms in rare gases at 300°k 2119

E-3.2. Diffusion coefficient of vibrationally excited (00°1) CO_2 in parent gas as a function of the temperature 2120

General References

C.F. Curtiss, "Transport Phenomena in Gases," in H. Eyring (Ed.), "Annual Review of Physical Chemistry," 18, 125, Annual Reviews, Inc., Palo Alto, California (1967).

C. F. Curtiss, "Survey of Kinetic Theory," in W. Jost (Ed.), "Physical Chemistry, An Advanced Treatise," VIA, 78, Academic, New York (1974).

J. O. Hirschfelder, C. F. Curtiss, and R. B. Bird, "Molecular Theory of Gases and Liquids," Wiley, New York (1964).

M. Klein, H. J. M. Hanley, F. J. Smith, and P. Holland, "Tables of Collision Integrals and Second Virial Coefficients for the (m,6,8) Intermolecular Potential Function," National Standard Reference Data Service, National Bureau of Standards (NSRDS-NBS-47), 47, 155 (June 1974).

T. R. Marrero and E. A. Mason, "Gaseous Diffusion Coefficients," J. Phys. Chem. Ref. Data 1, (1), 1-118 (1972).

E. A. Mason, "Transport in Neutral Gases," in A. R. Hochstim (Ed.), "Kinetic Processes in Gases and Plasmas," pg. 57, Academic, New York (1969).

E. A. Mason and T. R. Marrero, "The Diffusion of Atoms and Molecules," in D. R. Bates and I. Estermann (Eds.), "Advances in Atomic and Molecular Physics," 6, 155 (1970), Academic, New York.

E. W. Montroll and M. S. Green, "Statistical Mechanics of Transport and Nonequilibrium Processes," in G. K. Rollefson (Ed.), "Annual Review of Physical Chemistry," 5, 449, Annual Reviews, Inc., Palo Alto, California (1954).

H. Moraal, "Quantum Kinetic Theory of Polyatomic Gases," Physics Reports 17, 225 (1975).

J. H. Kolts and D. W. Setser, "Decay Rates of Ar(4s, $^3P_2$), Ar(4s', $^3P_0$), Kr(5s, $^3P_2$), and Xe(6s, $^3P_2$) Atoms in Argon," J. Chem. Phys. 68, 4848 (1978).

Tabular Data E-3.1. Diffusion coefficients and two-body and three-body destruction rates for metastable rare gas atoms in rare gases at 300°K.

Units: D_o is in units of 10^{18} $cm^{-1}sec^{-1}$; k_1 (two-body rate) is in units of 10^{-15} cm^3/sec; k_2 is in units of 10^{-32} cm^6/sec.

System	D_o	k_1	k_2
$Ar(^3P_2)$ - Ar	1.8 ± 0.1	2.1 ± 0.3	1.1 ± 0.4
$Ar(^3P_0)$ - Ar	1.8 ± 0.1	5.3 ± 0.9	0.83 ± 0.3
$Kr(^3P_2)$ - Ar	2.7 ± 0.2	0.69 ± 0.06	0.10 ± 0.04
$Xe(^3P_2)$ - Ar	2.5 ± 0.2	0.50 ± 0.07	0.03 ± 0.03
$Kr(^3P_2)$ - Kr	0.94	2.4	2.6
$Xe(^3P_2)$ - Xe	0.57	2.9*	5.0*

*Estimates only; obtained by "averaging" data from two or more sources which are in significant disagreement. See the reference for a more detailed comparison, as well as some sketchy data on other states.

Reference: These data were taken from J. H. Kolts and D. W. Setser, J. Chem. Phys. 68, 4848 (1978). This paper contains a survey of earlier data, along with comments and references.

Tabular Data E-3.2. Diffusion coefficient of vibrationally excited (00°1) CO_2 in parent gas as a function of the temperature.

Units: Temperature is in degrees Kelvin; D is in $cm^2 sec^{-1} atm$.

Temperature	D
300	0.079
350	0.122
400	0.163
450	0.209
500	0.261
550	0.316
600	0.373
650	0.440
700	0.503
750	0.566
800	0.641
850	0.716
900	0.799

Reference: These data were taken from L. Doyennette, M. Margottin-Maclou, H. Gueguen, A. Carion, and L. Henry, J. Chem. Phys. 60, 697 (1974). Information on the relaxation rate is included there. Data for N_2O are also included.

F. INTERACTIONS WITH STATIC ELECTRIC AND MAGNETIC FIELDS

General References

The following references are in addition to those of Chapter F of Volume II.

J.E. Bayfield, Excited Atomic and Molecular States in Strong Electromagnetic Fields, Physics Reports 51, 317-391 (1979).

K. A. Smith et al., Discrete Energy Transfer in Collisions of Xe(nf) Rydberg Atoms with NH_3, Phys. Rev. Letts. 40, 1362 (1978).

P. M. Koch, Resonant States in the Nonperturbative Regime: The Hydrogen Atom, Phys. Rev. Letts. 41, 99 (1978).

H. J. Silverstone, Perturbation Theory of the Stark Effect in Hydrogen to Arbitrarily High Order, Phys. Rev. A18, 1853 (1978).

M. G. Littman et al., Field Ionization Processes in Excited Atoms, Phys. Rev. Letts. 41, 103 (1978).

R. R. Freeman and G. C. Bjorklund, Effects of Electric Fields upon Autoionizing States of Sr, Phys. Rev. Letts. 40, 118 (1978).

Note: The above review by Bayfield appears to be an excellent review of the present state of the field.

G. PARTICLE PENETRATION IN GASES (IONS, NEUTRALS, AND ELECTRONS)

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General References

H. H. Anderson and J. F. Ziegler, The Stopping and Ranges of Ions in Matter, Vols. 1-5, Pergamon Press, N.Y. (Publication of the volumes commenced in 1977.)

J. F. Ziegler, "The Electronic and Nuclear Stopping of Energetic Ions," Appl. Phys. Letts. 31, 544-546 (1977).

T. E. Pierce and M. Blann, "Stopping Powers and Ranges of 5-90 MeV S, Cl, Br, and I Ions in H_2, He, N_2, Ar, and Kr: A Semiempirical Stopping Power Theory for Heavy Ions in Gases and Solids," Phys. Rev. 173. 390-405 (1968).

Definitions and Comments

The "stopping cross section" (or stopping power) is defined by the relation

$$S = -\frac{1}{N}\frac{dE(x)}{dx}$$

where N is the number density of target particles, E is the energy of the incident particles, and x is the distance through the target traversed by the incident particles. The units of the stopping power have been taken to be 10^{-15} eV-cm^2/atom. Another common unit for stopping powers is MeV-cm^2/mg. The present results must be divided by 0.6023/W to obtain these units where W is the atomic weight of the target element.

The "range" is defined by the relation

$$R(E) = -\frac{1}{N}\int_0^E \frac{1}{S(E')}\, dE'$$

and posesses units of distance (taken to be cm in this compilation). Note that range is dependent upon the number density of the target gas.

The data in Section G are largely based upon the massive and comprehensive five-volume work (currently being completed) by J. J. Andersen and J. F. Ziegler: The Stopping and Ranges of Ions in Matter (Pergamon Press, New York). We are grateful to Dr. Ziegler for numerous personal communications and fruitful discussions. The tables and figures in

sections G-1 and G-2 were prepared using the fitting formulae of Volumes 3 and 4 of the above work. The electronic and nuclear contributions to the stopping power were computed separately and summed. This compilation presents the total stopping power, although it should be noted that the nuclear part was unimportant except at the lowest energies reported.

Sections G-1 and G-2 represent an extension to additional target gases and, we believe an improvement in accuracy over the proton and He results presented in Vol. II of our compilation.

Section G-3 contains results generated using a scaling formula developed by J. F. Ziegler [Appl. Phys. Letts. 31, 544 (1977)], which scales the proton stopping cross sections in gases to heavy particle cross sections in the same gases. It should be noted that this scaling formula does not work for He projectiles. Also, a small adjustment in the middle energy fit for proton stopping powers was made to avoid a discontinuity in the heavy particle results; this discontinuity does not show up for protons.

The results obtained using the scaling formula of Ziegler were compared with experimental data when available. Such results, especially on gaseous targets of laser interest, are rare; however, when these results were available the agreement with the scaling formula was excellent. Volume 5 of the work of Anderson and Ziegler (still to be published) will contain results for heavy ions in all target materials.

Finally, there is some question that the stopping powers and ranges of fission fragments can be accurately approximated by those of "normal" heavy ions produced by an accelerator, since the fission fragments are frequently highly ionized and because the nuclear masses of the fragments are not always those of the more common isotopes of the corresponding elements. However, it has not been shown either experimentally or theoretically that the stopping power depends on the mass of the projectile. Rather, it appears to depend only on the nuclear charge.

G-1. STOPPING POWER AND RANGE OF PROTONS IN GASES

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Tabular Data G-1.1. Stopping power of protons in H, He, Ne, Ar, Kr, and Xe.

Units are: Proton Energy in MeV,
Stopping Power in 10^{-15} eV-cm^2/atom

Energy	Hydrogen	Helium	Neon	Argon	Krypton	Xenon
.001	1.48	1.41	2.26	6.04	6.72	8.51
.002	1.94	1.87	2.99	8.55	9.33	11.9
.004	2.62	2.55	4.08	11.6	13.0	16.7
.007	3.41	3.31	5.30	15.3	17.1	21.9
.010	4.04	3.93	6.29	18.3	20.4	26.2
.015	4.73	4.65	7.47	21.6	24.3	31.2
.020	5.24	5.21	8.43	24.3	27.3	35.2
.030	5.91	6.02	9.95	28.1	31.8	41.4
.050	6.42	6.93	12.0	32.1	36.8	49.1
.075	6.30	7.28	13.6	33.3	38.7	53.5
.100	5.85	7.17	14.4	32.2	37.9	54.2
.150	4.84	6.45	14.7	28.2	34.1	50.5
.200	4.01	5.65	14.1	24.6	30.4	45.0
.300	2.96	4.40	12.3	19.7	25.5	36.3
.500	1.97	3.07	9.40	14.9	20.5	27.3
.750	1.43	2.29	7.40	11.9	17.1	22.2
1.000	1.14	1.86	6.20	10.1	14.9	19.2
1.500	.823	1.40	4.86	7.75	11.7	14.8
2.000	.652	1.12	4.00	6.42	9.93	12.6
3.000	.467	.809	3.00	4.87	7.74	9.97
5.000	.306	.536	2.06	3.38	5.55	7.29
7.500	.218	.385	1.51	2.51	4.20	5.60
10.000	.171	.303	1.21	2.02	3.42	4.61
15.000	.121	.217	.860	1.46	2.55	3.47
20.000	.095	.171	.701	1.16	2.06	2.85
30.000	.068	.122	.506	.862	1.52	2.11
50.000	.044	.081	.340	.550	1.04	1.45
75.000	.032	.058	.249	.426	.769	1.08
100.000	.026	.047	.201	.345	.625	.882

Tabular Data G-1.2. Stopping power of protons in F, Cl, Br, and I.

Units are: Proton Energy in MeV,
Stopping Power in 10^{-15} eV-cm^2/atom

Energy	Fluorine	Chlorine	Bromine	Iodine
.001	2.37	5.37	5.92	8.01
.002	3.17	7.39	8.20	11.2
.004	4.33	10.3	11.4	15.7
.007	5.64	13.5	15.0	20.6
.010	6.70	16.1	17.9	24.6
.015	7.96	19.1	21.3	29.3
.020	8.98	21.5	24.0	33.1
.030	10.6	25.0	28.2	38.9
.050	12.7	29.2	33.4	45.3
.075	14.2	31.1	36.2	50.6
.100	14.9	30.9	36.6	51.4
.150	14.9	28.1	34.3	48.3
.200	14.0	24.8	31.0	43.3
.300	12.0	19.8	25.9	35.1
.500	9.05	14.7	20.4	26.6
.750	7.07	11.6	16.9	21.7
1.000	5.91	9.73	14.7	18.8
1.500	4.56	7.43	11.6	14.3
2.000	3.74	6.15	9.79	12.2
3.000	2.80	4.66	7.62	9.67
5.000	1.92	3.25	5.45	7.07
7.500	1.41	2.39	4.12	5.43
10.000	1.12	1.92	3.36	4.48
15.000	.816	1.41	2.50	3.38
20.000	.649	1.13	2.02	2.75
30.000	.470	.819	1.49	2.05
50.000	.313	.551	1.02	1.41
75.000	.229	.404	.752	1.05
100.000	.165	.327	.611	.853

Tabular Data G-1.3. Stopping power of protons in C, N, O, and S.

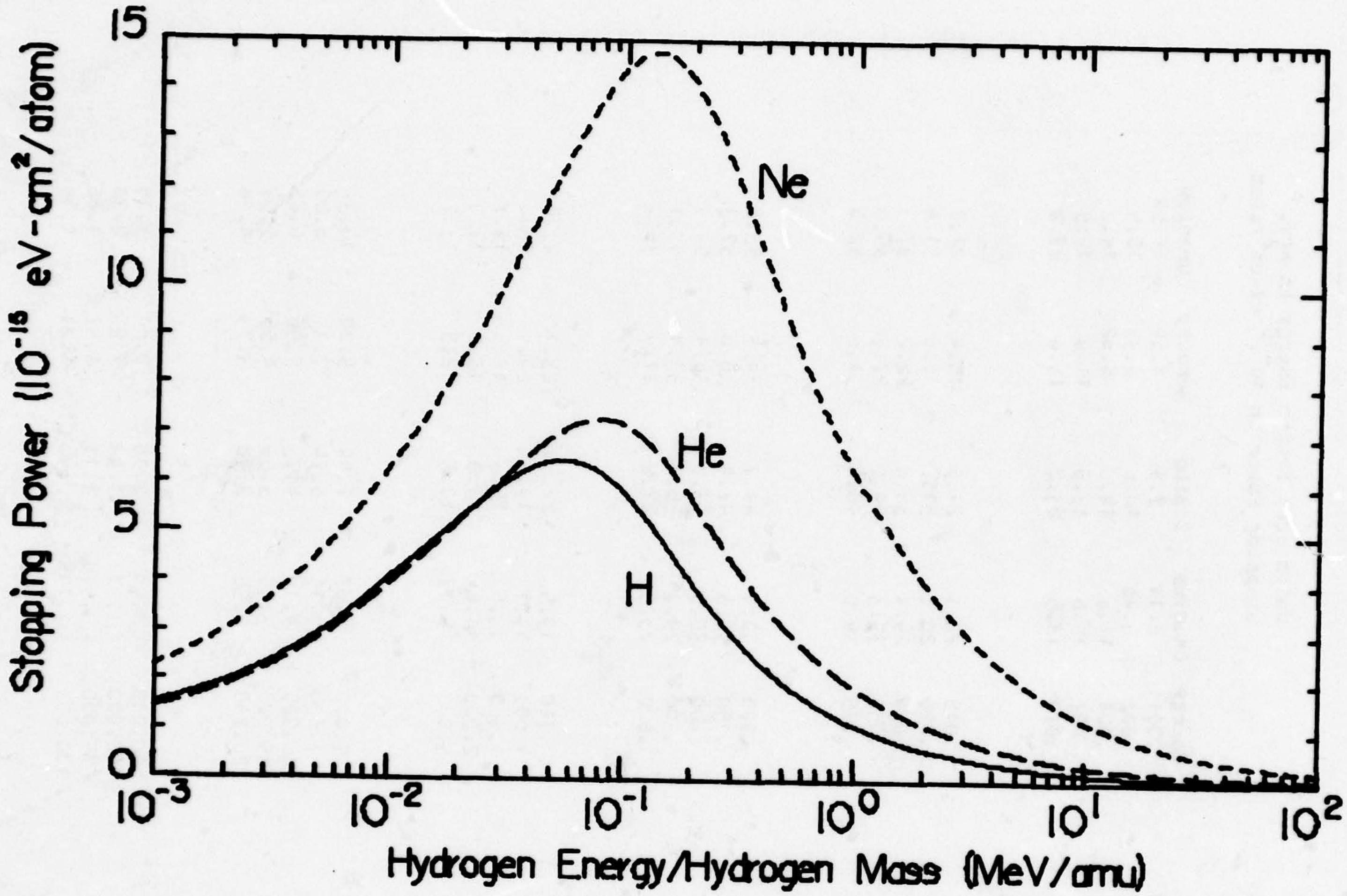
Units are: Proton Energy in MeV,
Stopping Power in 10^{-15} eV-cm^2/atom

Energy	Carbon	Nitrogen	Oxygen	Sulfur
.001	2.90	3.24	2.94	3.76
.002	3.92	4.39	3.97	5.14
.004	5.41	6.07	5.47	7.10
.007	7.08	7.94	7.15	9.26
.010	8.42	9.44	8.50	11.0
.015	9.94	11.2	10.1	13.1
.020	11.1	12.5	11.3	14.8
.030	12.8	14.8	13.2	17.4
.050	14.8	16.9	15.6	20.8
.075	15.0	17.8	16.9	23.0
.100	14.8	17.7	17.1	23.7
.150	12.9	16.0	16.1	23.0
.200	11.4	14.1	14.8	21.3
.300	9.31	11.3	11.9	17.8
.500	7.02	8.18	8.76	13.5
.750	5.51	6.31	6.83	10.7
1.000	4.59	5.22	5.68	9.05
1.500	3.45	3.90	4.28	7.08
2.000	2.80	3.18	3.50	5.86
3.000	2.08	2.36	2.61	4.43
5.000	1.40	1.60	1.76	3.07
7.500	1.02	1.17	1.30	2.27
10.000	.813	.930	1.04	1.82
15.000	.587	.672	.752	1.33
20.000	.465	.533	.597	1.07
30.000	.335	.384	.431	.777
50.000	.222	.255	.287	.522
75.000	.162	.186	.209	.383
100.000	.130	.150	.168	.310

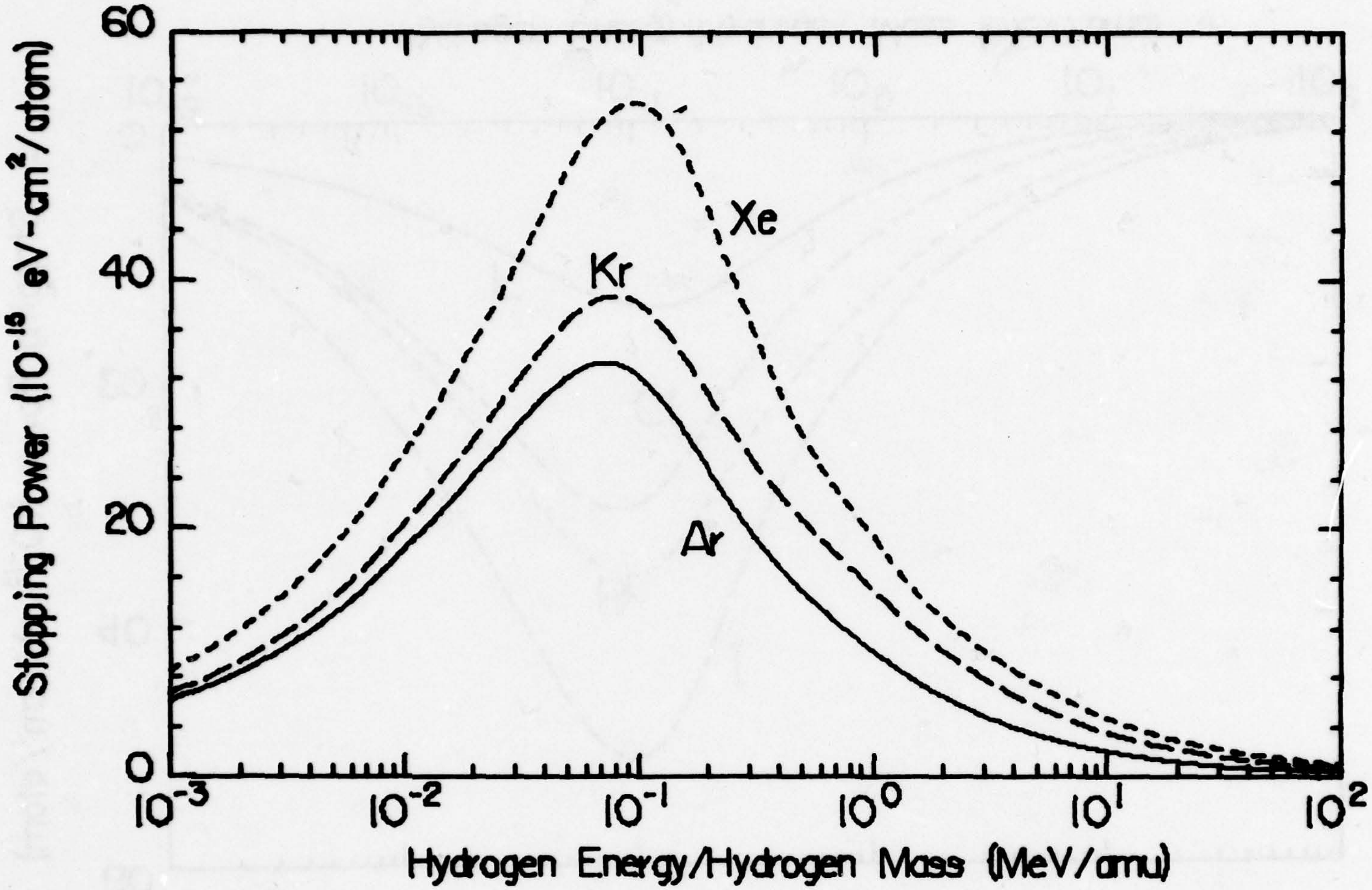
Tabular Data G-1.4. Stopping power of protons in Cd, Cs, Hg, and U.

Units are: Proton Energy in MeV,
Stopping Power in 10^{-15} eV-cm^2/atom

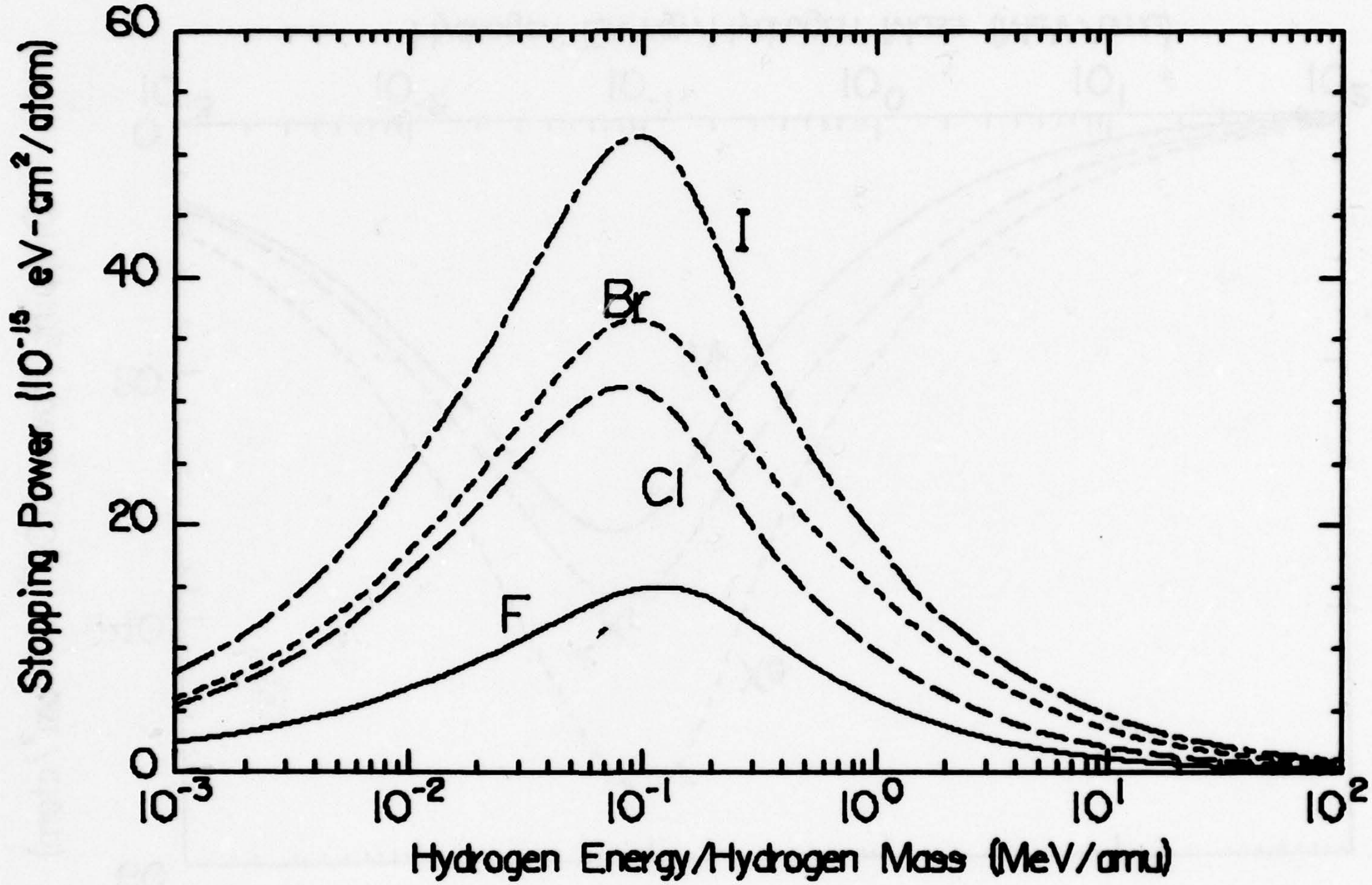
Energy	Cadmium	Cesium	Mercury	Uranium
.001	6.11	7.56	4.54	7.50
.002	8.46	10.0	6.33	10.5
.004	11.8	14.8	8.82	14.8
.007	15.6	19.5	11.0	19.5
.010	18.5	23.2	13.0	23.2
.015	22.1	27.6	16.4	27.7
.020	25.0	31.2	18.6	31.4
.030	29.4	36.8	22.2	37.3
.050	35.3	44.0	27.3	45.6
.075	39.0	48.4	31.6	52.0
.100	40.1	49.7	34.3	55.6
.150	38.6	47.4	36.6	57.3
.200	35.5	43.0	36.4	54.9
.300	29.9	35.5	33.4	47.1
.500	23.5	27.2	27.4	35.2
.750	19.5	22.3	23.1	27.8
1.000	17.1	19.3	20.4	23.8
1.500	13.6	15.3	17.5	19.7
2.000	11.6	13.0	15.2	17.0
3.000	9.17	10.3	12.3	13.7
5.000	6.67	7.49	9.20	10.3
7.500	5.11	5.74	7.17	8.00
10.000	4.19	4.73	5.96	6.66
15.000	3.15	3.56	4.55	5.09
20.000	2.56	2.90	3.73	4.18
30.000	1.91	2.16	2.81	3.15
50.000	1.31	1.49	1.96	2.20
75.000	.976	1.11	1.47	1.66
100.000	.795	.903	1.21	1.36



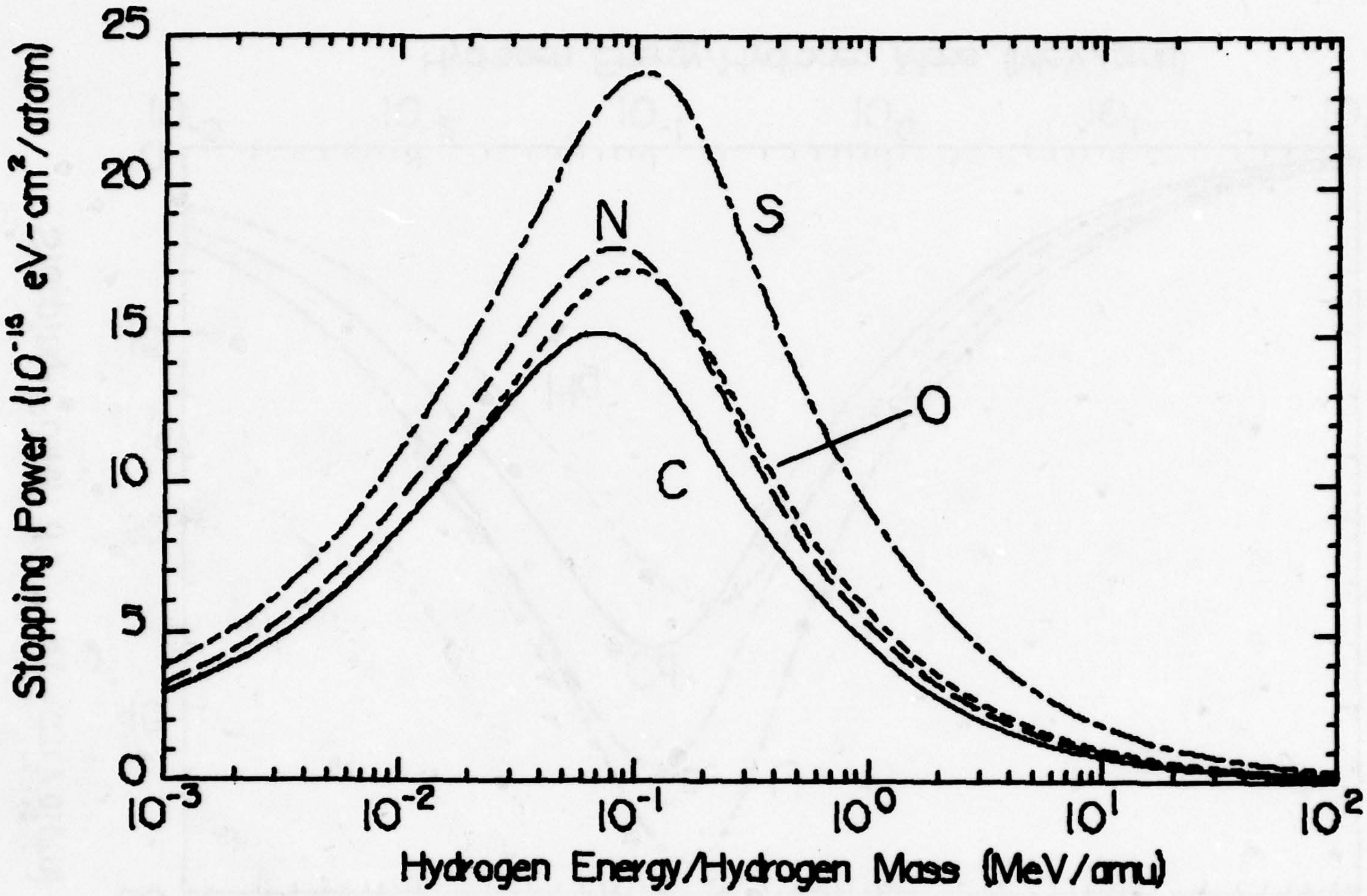
Graphical Data G-1.5. Stopping power of protons in H, He, and Ne.



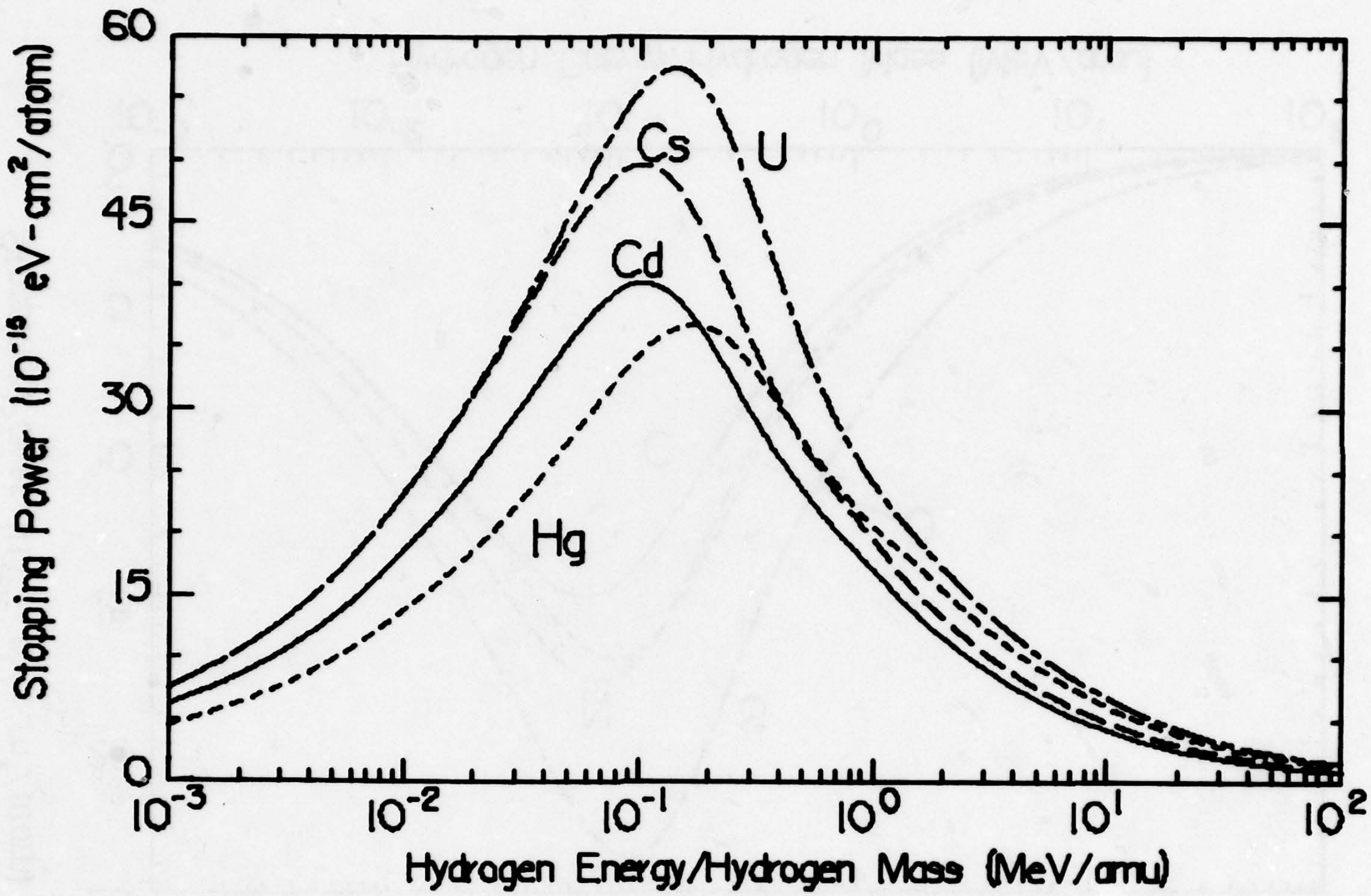
Graphical Data G-1.6. Stopping power of protons in Ar, Kr, and Xe.



Graphical Data G-1.7. Stopping power of protons in F, Cl, Br, and I.



Graphical Data G-1.8. Stopping power of protons in C, N, O, and S,



Graphical Data G-1.9. Stopping power of protons in Hg, Cd, Cs, and U.

Tabular Data G-1.10. Path length of protons in H, He, Ne, Ar, Kr, and Xe.

Units are: Proton Energy in MeV, Path Length in cm
Density: 2.688×10^{19} atoms/cm^3

Energy	Hydrogen	Helium	Neon	Argon	Krypton	Xenon
.001	.032	.035	.024	.011	.011	.009
.002	.054	.058	.039	.016	.015	.012
.004	.086	.091	.060	.024	.022	.017
.007	.123	.129	.083	.032	.029	.023
.010	.153	.160	.103	.039	.035	.028
.015	.196	.203	.130	.048	.043	.034
.020	.233	.241	.153	.056	.051	.040
.030	.299	.307	.194	.070	.063	.050
.050	.419	.421	.261	.095	.085	.066
.075	.564	.551	.333	.123	.109	.084
.100	.717	.679	.400	.151	.133	.101
.150	1.07	.952	.526	.213	.185	.136
.200	1.49	1.26	.655	.284	.243	.175
.300	2.58	2.01	.938	.454	.377	.268
.500	5.74	4.07	1.64	.894	.706	.508
.750	11.4	7.62	2.76	1.60	1.20	.890
1.000	18.7	12.2	4.14	2.45	1.79	1.34
1.500	38.2	23.7	7.53	4.59	3.22	2.48
2.000	63.8	38.7	11.8	7.24	4.95	3.85
3.000	132.	78.5	22.7	14.0	9.24	7.20
5.000	334.	194.	53.2	32.7	20.8	16.1
7.500	700.	402.	107.	65.0	40.3	30.8
10.000	1186.	677.	176.	107.	65.0	49.2

Tabular Data G-1.11. Path length of protons in F, Cl, Br, and I.

Units are: Proton Energy in MeV, Path Length in cm
Density: 2.688×10^{19} atoms/cm^3

Energy	Fluorine	Chlorine	Bromine	Iodine
.001	.024	.012	.012	.009
.002	.037	.018	.017	.013
.004	.057	.027	.025	.018
.007	.079	.036	.033	.025
.010	.097	.043	.040	.030
.015	.123	.054	.049	.036
.020	.145	.063	.058	.042
.030	.183	.079	.072	.053
.050	.246	.106	.096	.070
.075	.315	.137	.122	.089
.100	.379	.167	.148	.107
.150	.503	.230	.200	.144
.200	.631	.300	.257	.185
.300	.919	.469	.389	.281
.500	1.64	.913	.716	.528
.750	2.82	1.64	1.22	.919
1.000	4.27	2.52	1.81	1.38
1.500	7.88	4.74	3.26	2.56
2.000	12.4	7.51	5.02	3.98
3.000	24.1	14.5	9.37	7.43
5.000	56.9	34.1	21.1	16.6
7.500	114.	68.0	41.0	31.7
10.000	189.	112.	66.1	50.7

Tabular Data G-1.12. Path length of protons in C, N, O, and S.

Units are: Proton Energy in MeV, Path Length in cm
Density: 2.688×10^{19} atoms/cm^3

Energy	Carbon	Nitrogen	Oxygen	Sulfur
.001	.019	.018	.019	.017
.002	.030	.028	.030	.025
.004	.046	.042	.046	.037
.007	.064	.058	.064	.051
.010	.079	.071	.078	.062
.015	.099	.089	.098	.077
.020	.116	.104	.115	.090
.030	.147	.132	.145	.113
.050	.201	.179	.197	.152
.075	.264	.232	.254	.194
.100	.326	.284	.308	.234
.150	.462	.394	.420	.313
.200	.615	.518	.541	.397
.300	.978	.815	.825	.589
.500	1.91	1.60	1.56	1.08
.750	3.42	2.91	2.78	1.86
1.000	5.28	4.54	4.28	2.81
1.500	10.0	8.74	8.11	5.14
2.000	16.0	14.1	12.9	8.04
3.000	31.7	27.8	25.4	15.4
5.000	76.2	66.9	60.7	36.0
7.500	155.	136.	123.	71.7
10.000	258.	226.	203.	118.

Tabular Data G-1.13. Path length of protons in Cd, Cs, Hg, and U.

Units are: Proton Energy in MeV, Path Length in cm
Density: 2.688×10^{19} atoms/cm^3

Energy	Cadmium	Cesium	Mercury	Uranium
.001	.012	.010	.016	.010
.002	.017	.014	.023	.014
.004	.024	.020	.033	.020
.007	.032	.026	.044	.026
.010	.039	.031	.052	.032
.015	.048	.039	.065	.039
.020	.056	.045	.075	.045
.030	.070	.056	.093	.056
.050	.092	.074	.123	.074
.075	.117	.094	.155	.093
.100	.141	.113	.183	.110
.150	.188	.151	.235	.143
.200	.238	.192	.286	.176
.300	.353	.288	.392	.249
.500	.637	.531	.639	.434
.750	1.07	.912	1.01	.735
1.000	1.59	1.36	1.44	1.10
1.500	2.82	2.46	2.41	1.96
2.000	4.31	3.79	3.56	2.98
3.000	7.94	7.04	6.29	5.44
5.000	17.6	15.7	13.4	11.8
7.500	33.7	30.0	24.9	22.2
10.000	53.9	48.0	39.2	35.0

Tabular Data G-1.14. Projected range of protons in H, He, Ne, Ar, Kr, and Xe.

Units are: Proton Energy in MeV, Range in cm
Density: 2.688×10^{19} atoms/cm^3

Energy	Hydrogen	Helium	Neon	Argon	Krypton	Xenon
.001	.014	.013	.004	.001	.001	.001
.002	.031	.028	.010	.003	.002	.001
.004	.060	.058	.019	.006	.003	.002
.007	.100	.095	.033	.010	.006	.004
.010	.135	.129	.046	.013	.009	.005
.015	.183	.181	.069	.019	.013	.008
.020	.222	.224	.091	.025	.016	.010
.030	.292	.294	.130	.037	.024	.015
.050	.419	.413	.199	.060	.038	.024
.075	.564	.551	.283	.086	.058	.036
.100	.717	.679	.360	.114	.079	.048
.150	1.07	.952	.497	.179	.124	.078
.200	1.49	1.26	.630	.254	.175	.110
.300	2.58	2.01	.918	.427	.302	.187
.500	5.74	4.07	1.64	.867	.636	.405
.750	11.4	7.62	2.76	1.58	1.14	.783
1.000	18.7	12.2	4.14	2.45	1.72	1.24
1.500	38.2	23.7	7.53	4.59	3.15	2.37
2.000	63.8	38.7	11.8	7.24	4.90	3.73
3.000	132.	78.5	22.7	14.0	9.24	7.10
5.000	334.	194.	53.2	32.7	20.8	16.1
7.500	700.	402.	107.	65.0	40.3	30.8
10.000	1186.	677.	176.	107.	65.0	49.2

Tabular Data G-1.15. Projected range of protons in F, Cl, Br, and I.

Units are: Proton Energy in MeV, Range in cm
Density: 2.688×10^{19} atoms/cm^3

Energy	Fluorine	Chlorine	Bromine	Iodine
.001	.005	.001	.001	.001
.002	.010	.003	.002	.001
.004	.019	.007	.004	.002
.007	.033	.011	.007	.004
.010	.046	.015	.010	.006
.015	.069	.022	.014	.009
.020	.090	.029	.019	.011
.030	.127	.043	.027	.016
.050	.195	.069	.044	.026
.075	.276	.098	.066	.039
.100	.348	.129	.089	.052
.150	.479	.197	.135	.083
.200	.611	.272	.187	.117
.300	.904	.444	.314	.197
.500	1.64	.889	.648	.423
.750	2.82	1.62	1.15	.813
1.000	4.27	2.52	1.75	1.28
1.500	7.88	4.74	3.20	2.45
2.000	12.4	7.51	4.97	3.86
3.000	24.1	14.5	9.37	7.32
5.000	56.9	34.1	21.1	16.6
7.500	114.	68.0	41.0	31.7
10.000	189.	112.	66.1	50.7

Tabular Data G-1.16. Projected range of protons in C, N, O, and S.

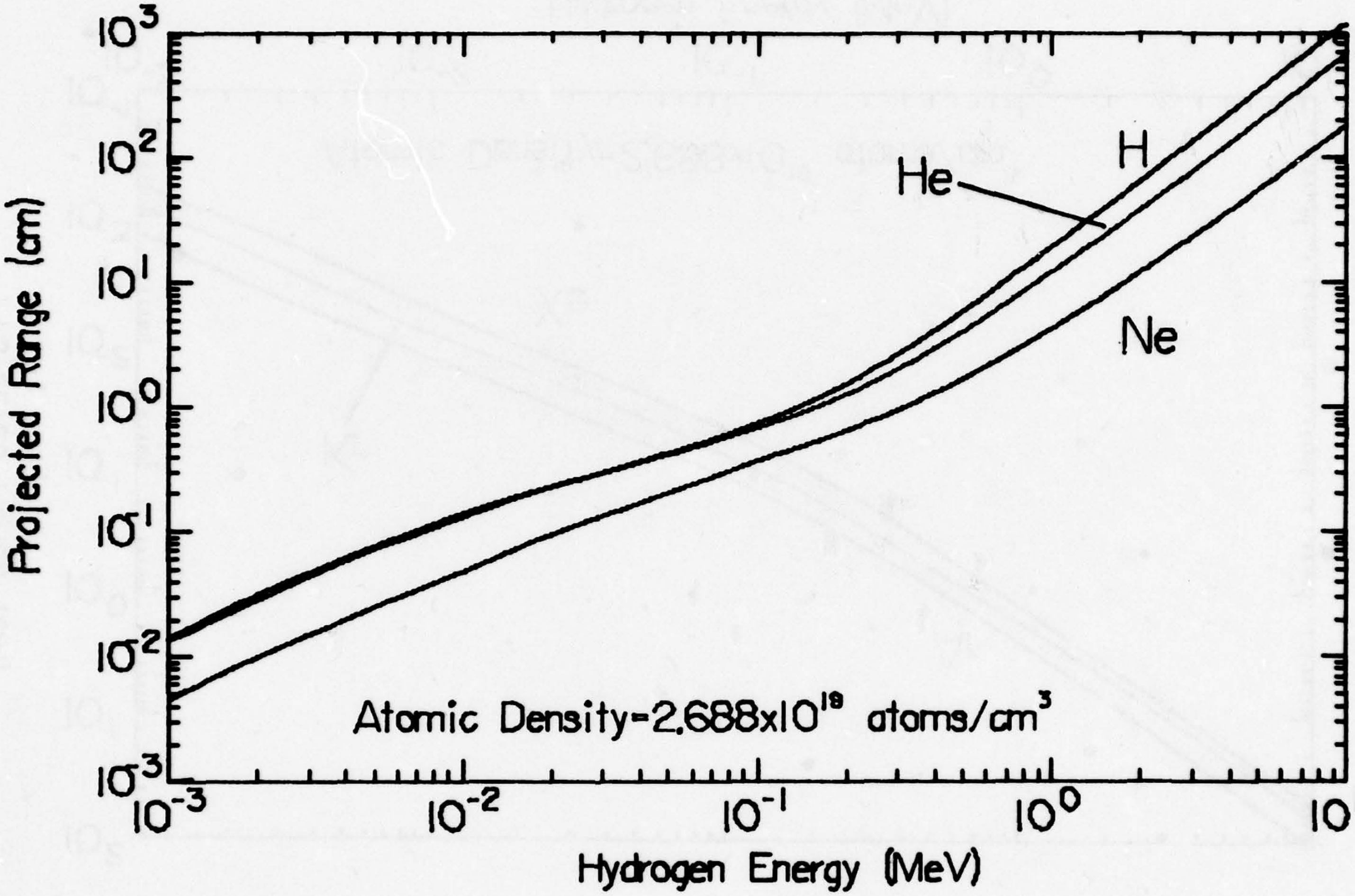
Units are: Proton Energy in MeV, Range in cm
Density: 2.688×10^{19} atoms/cm^3

Energy	Carbon	Nitrogen	Oxygen	Sulfur
.001	.005	.004	.004	.002
.002	.009	.008	.008	.005
.004	.019	.016	.016	.010
.007	.032	.027	.028	.016
.010	.046	.038	.039	.022
.015	.065	.055	.058	.033
.020	.082	.070	.075	.042
.030	.116	.099	.104	.063
.050	.179	.153	.161	.100
.075	.247	.213	.228	.142
.100	.312	.269	.287	.184
.150	.451	.381	.403	.273
.200	.607	.507	.527	.364
.300	.978	.815	.816	.560
.500	1.91	1.60	1.56	1.05
.750	3.42	2.91	2.78	1.84
1.000	5.28	4.54	4.28	2.81
1.500	10.0	8.74	8.11	5.14
2.000	16.0	14.1	12.9	8.04
3.000	31.7	27.8	25.4	15.4
5.000	76.2	66.9	60.7	36.0
7.500	155.	136.	123.	71.7
10.000	258.	226.	203.	118.

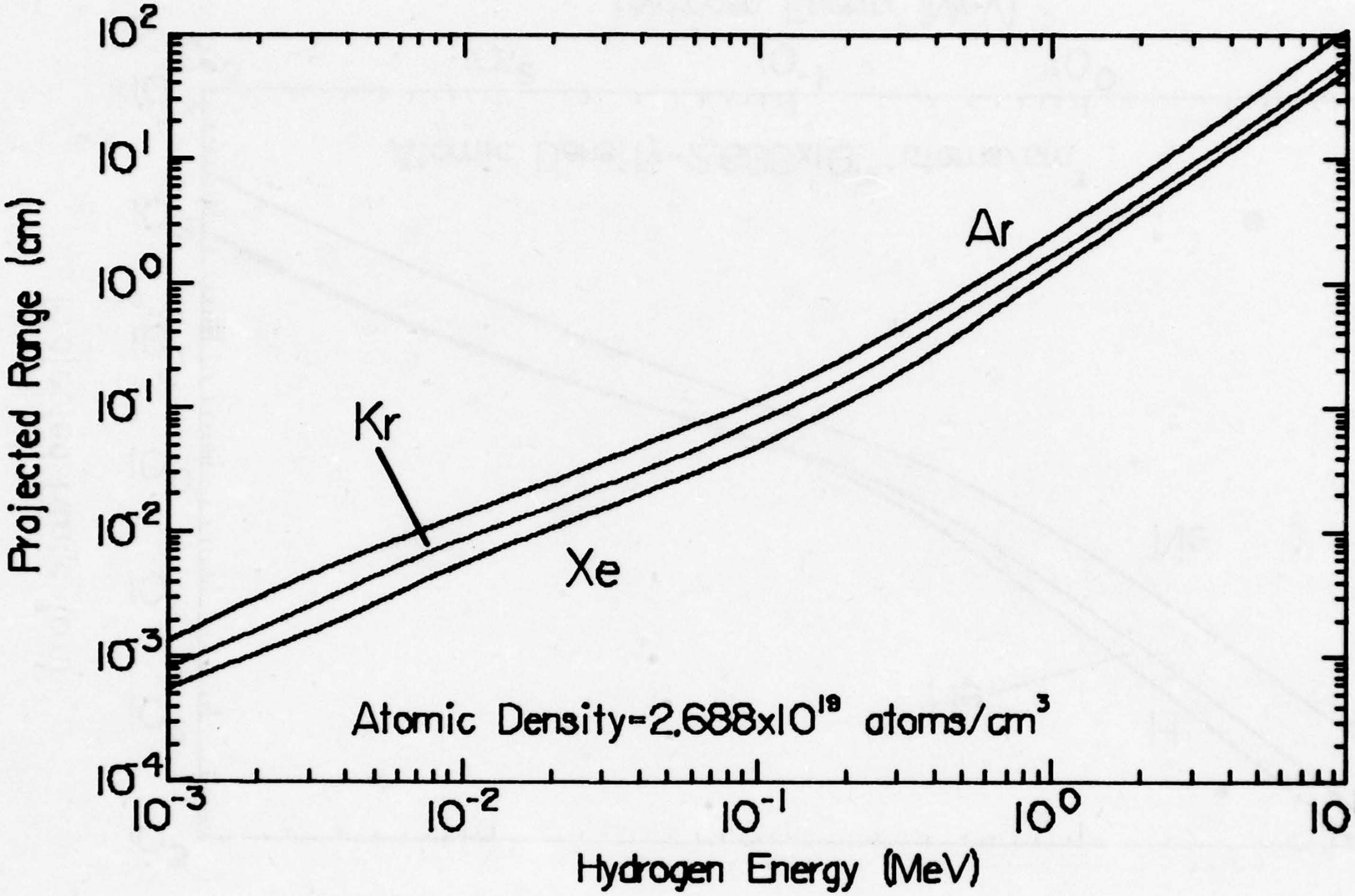
Tabular Data G-1.17. Projected range of protons in Cd, Cs, Hg, and U.

Units are: Proton Energy in MeV, Range in cm
Density: 2.688×10^{19} atoms/cm^3

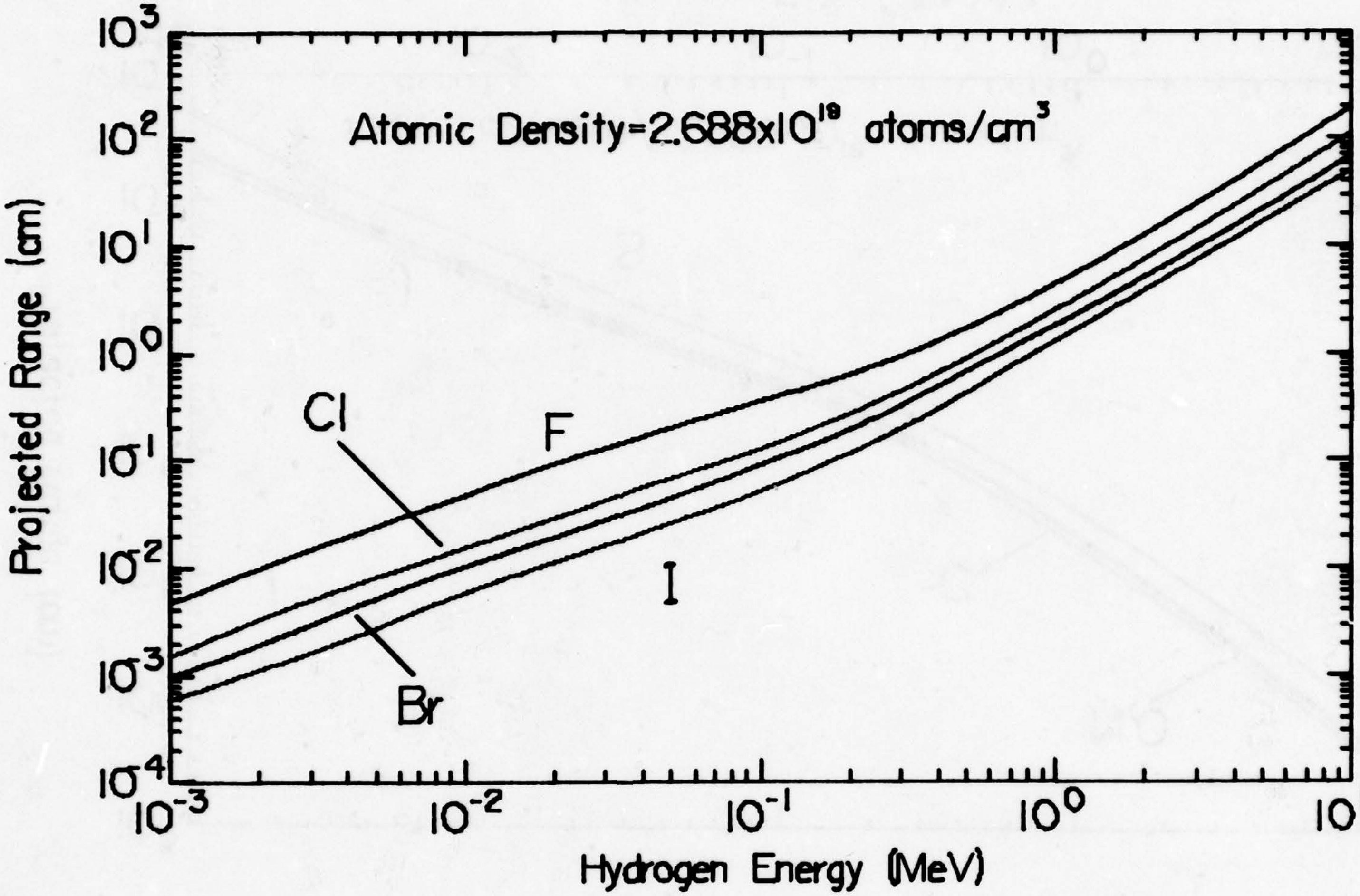
Energy	Cadmium	Cesium	Mercury	Uranium
.001	.001	.001	.001	.001
.002	.002	.001	.002	.001
.004	.003	.002	.003	.002
.007	.006	.004	.005	.003
.010	.008	.006	.008	.004
.015	.012	.009	.012	.006
.020	.016	.012	.016	.009
.030	.022	.017	.024	.013
.050	.036	.027	.038	.021
.075	.053	.040	.055	.031
.100	.072	.053	.073	.041
.150	.113	.085	.108	.061
.200	.156	.120	.147	.084
.300	.256	.200	.238	.141
.500	.528	.420	.446	.289
.750	.972	.799	.783	.542
1.000	1.48	1.25	1.20	.874
1.500	2.71	2.35	2.19	1.73
2.000	4.20	3.67	3.34	2.75
3.000	7.86	6.92	6.06	5.18
5.000	17.6	15.7	13.2	11.5
7.500	33.7	30.0	24.9	22.2
10.000	53.9	48.0	39.2	35.0



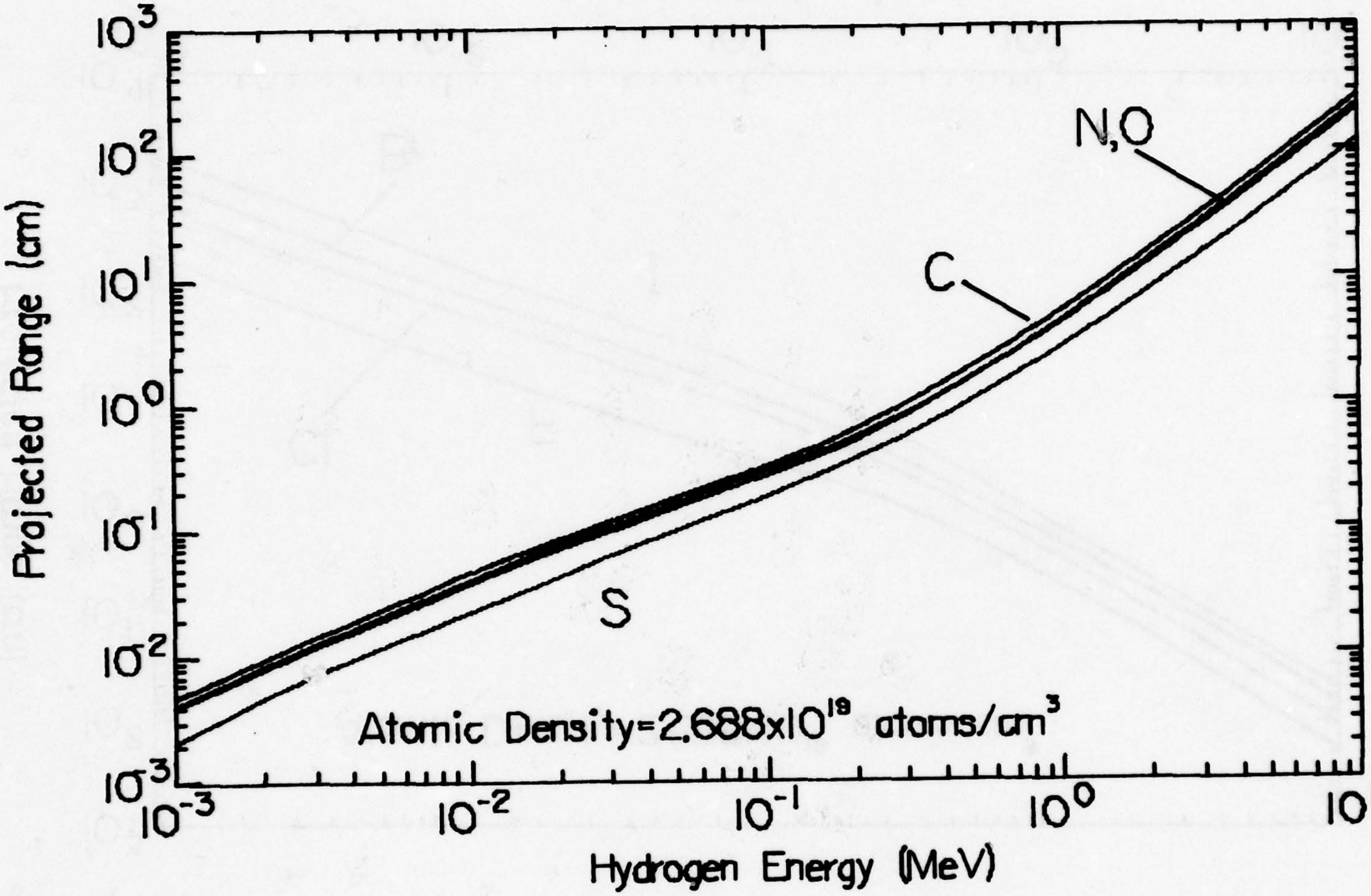
Graphical Data G-1.18. Projected range of protons in H, He, and Ne.



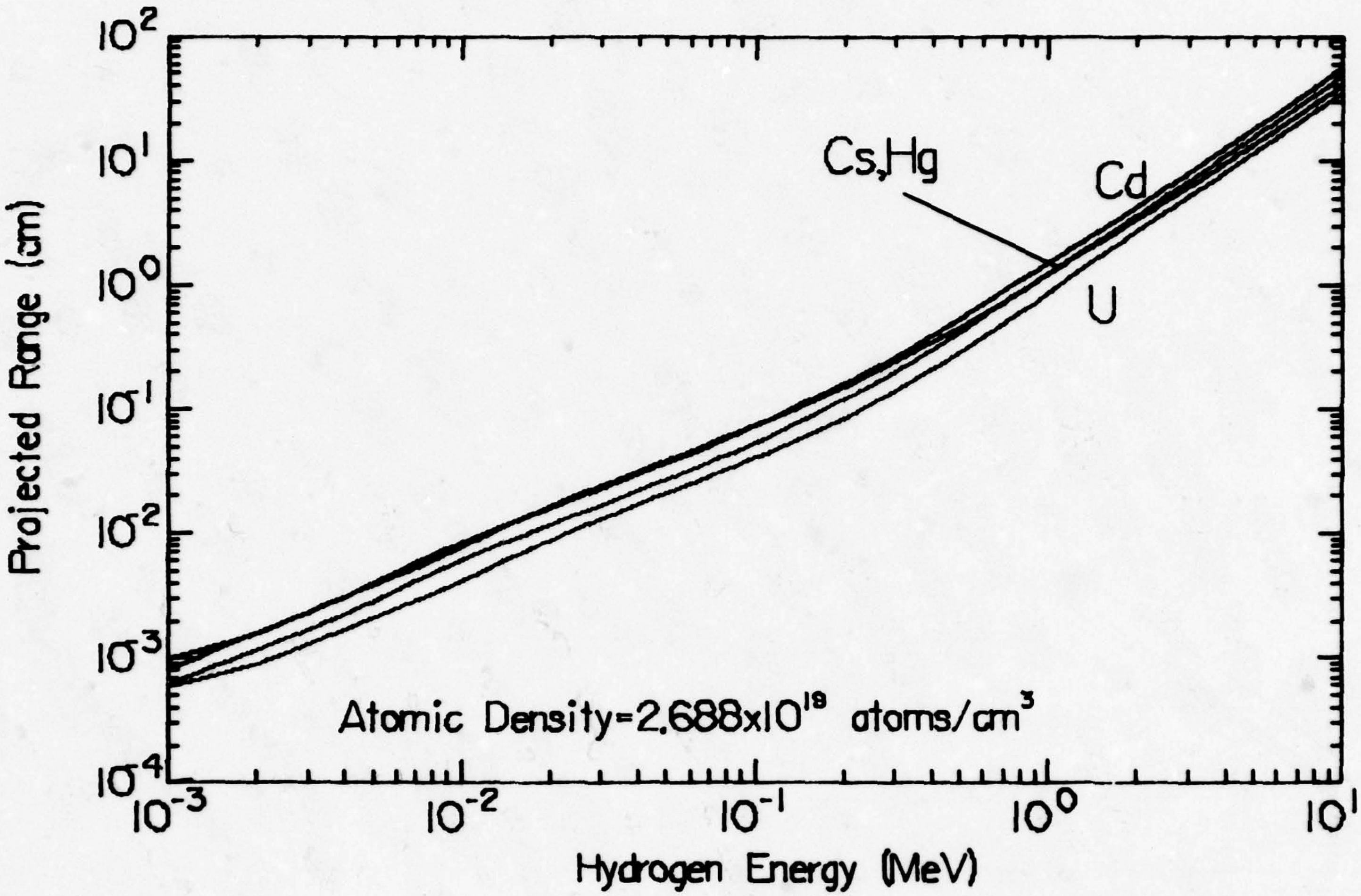
Graphical Data G-1.19. Projected range of protons in Ar, Kr, and Xe.



Graphical Data G-1.20. Projected range of protons in F, Cl, Br, and I.



Graphical Data G-1.21. Projected range of protons in C, N, O, and S.



Graphical Data G-1.22. Projected range of protons in Cd, Cs, Hg, and U.

G-2. STOPPING POWER AND RANGE OF HELIUM IONS IN GASES

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Tabular Data G-2.1. Stopping power of helium ions in H, He, Ne, Ar, Kr, and Xe.

Units are: Energy in MeV; Stopping Power in 10^{-15} eV-cm^2/atom

Energy	Hydrogen	Helium	Neon	Argon	Krypton	Xenon
0.001	1.68	1.97	5.05	5.05	3.88	6.00
0.002	1.58	1.92	5.40	5.85	4.69	8.20
0.004	1.66	2.08	6.19	7.29	5.91	11.3
0.007	1.89	2.43	7.27	9.26	7.59	14.9
0.010	2.13	2.75	8.20	11.0	9.18	18.0
0.015	2.52	3.25	9.54	13.6	11.7	22.5
0.020	2.88	3.71	10.7	16.0	14.0	26.5
0.030	3.55	4.55	12.7	20.2	18.3	33.6
0.050	4.71	5.96	15.9	27.3	26.0	45.5
0.075	5.95	7.44	19.1	34.8	34.6	58.0
0.100	7.02	8.71	21.7	41.2	42.4	68.7
0.150	8.78	10.8	26.1	52.1	56.1	87.0
0.200	10.2	12.5	29.5	60.9	67.8	102.
0.300	12.1	14.9	34.9	74.0	86.2	124.
0.500	13.5	17.2	41.3	86.3	106.	146.
0.750	13.1	17.6	44.7	86.7	109.	148.
1.00	11.9	16.7	45.0	80.8	103.	139.
1.50	9.44	14.2	41.9	67.7	88.5	118.
2.00	7.71	12.1	37.6	58.1	78.2	102.
3.00	5.65	9.32	30.4	46.3	65.2	84.0
5.00	3.79	6.44	22.1	34.4	51.1	65.5
7.50	2.75	4.71	16.9	26.8	41.2	53.0
10.0	2.18	3.75	13.9	22.2	34.9	45.1
15.0	1.56	2.72	10.3	16.7	27.0	35.4
20.0	1.23	2.15	8.34	13.6	22.3	29.5
30.0	0.88	1.54	6.11	10.1	16.9	22.6
50.0	0.57	1.01	4.09	6.80	11.7	15.8
75.0	0.40	0.72	2.96	4.96	8.63	11.8
100.0	0.32	0.57	2.35	3.96	6.95	9.59

Reference: These data were taken from J. F. Ziegler, Helium: Stopping Power and Ranges in all Elemental Matter, Pergamon (1977).

Tabular Data G-2.2. Stopping power of helium ions in C, N, O, S, Hg, and Cs.

Units are: Energy in MeV; Stopping Power in 10^{-15} eV-cm^2/atom

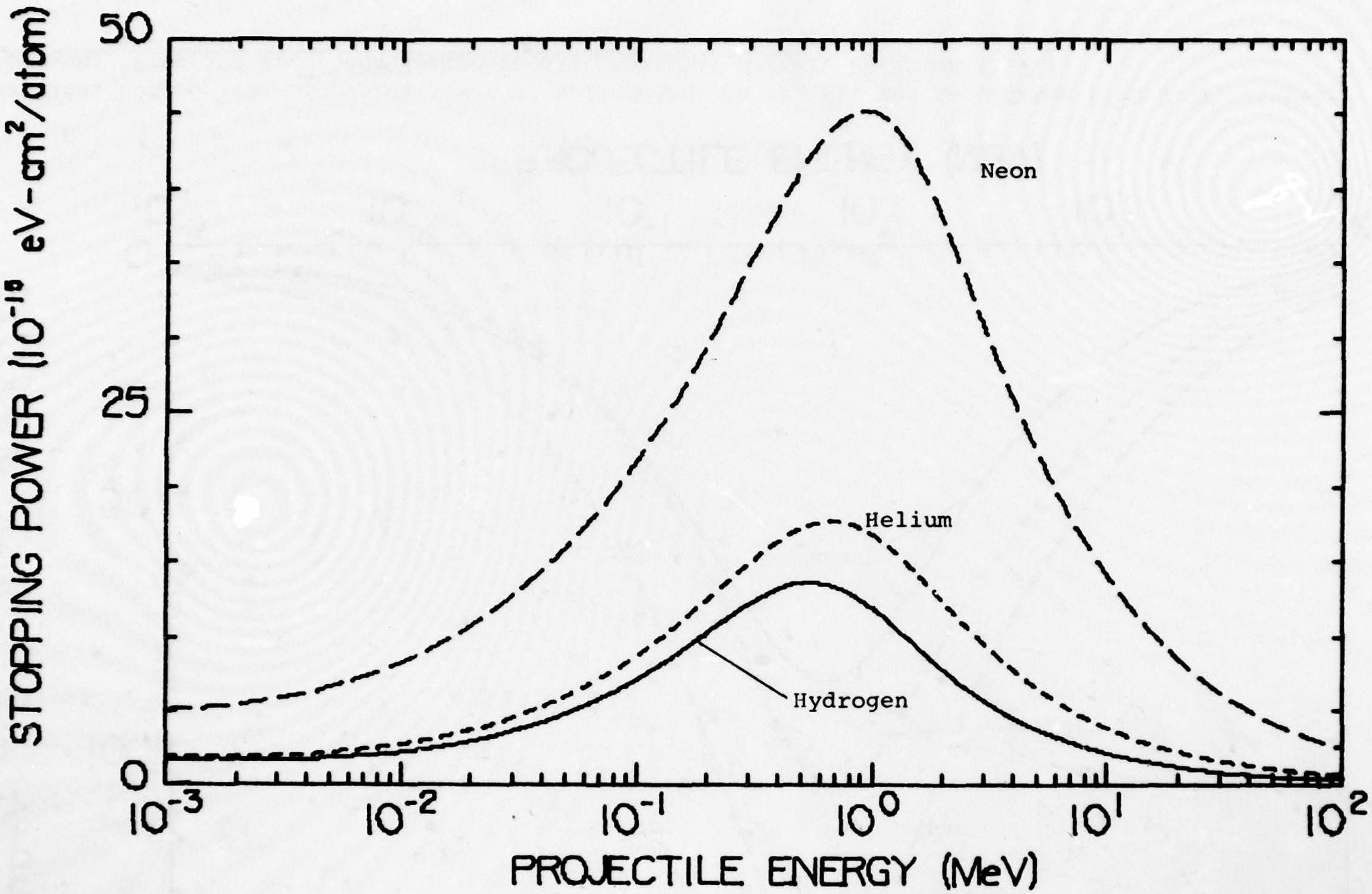
Energy	Carbon	Nitrogen	Oxygen	Sulfur	Mercury	Cesium
0.001		4.49	5.32			
0.002		4.86	5.84			
0.004		5.75	6.89			
0.007		6.98	8.23			
0.010		8.06	9.37			
0.015		9.65	11.0			
0.020		11.0	12.4			
0.030		13.5	14.8			
0.050		17.4	18.6			
0.075		21.4	22.3			
0.100	27.1	24.8	25.4	48.5	72.5	109.
0.150	31.7	30.4	30.4	60.1	86.9	123.
0.200	35.2	34.8	34.3	69.1	98.3	133.
0.300	39.9	41.1	40.0	81.0	115.	147.
0.500	43.8	47.3	46.0	89.1	135.	160.
0.750	43.3	48.1	47.7	85.4	141.	161.
1.00	40.5	45.6	46.2	77.9	138.	155.
1.50	34.1	38.5	40.4	64.9	124.	133.
2.00	28.9	32.7	34.9	55.7	111.	114.
3.00	22.2	25.2	27.2	44.3	93.3	88.4
5.00	15.6	17.9	19.4	32.3	74.7	65.5
7.50	11.7	13.6	14.7	24.7	61.8	53.3
10.0	9.50	11.1	12.0	20.1	53.5	46.3
15.0	7.05	8.14	8.90	15.2	43.3	36.3
20.0	5.65	6.52	7.16	12.3	36.7	30.3
30.0	4.11	4.73	5.22	9.10	28.7	23.1
50.0	2.72	3.13	3.48	6.14	20.5	16.2
75.0	1.96	2.25	2.51	4.47	15.6	12.1
100.0	1.55	1.78	1.99	3.57	12.7	9.8

Reference: These data were taken from J. F. Ziegler, Helium: Stopping Power and Ranges in all Elemental Matter, Pergamon (1977).

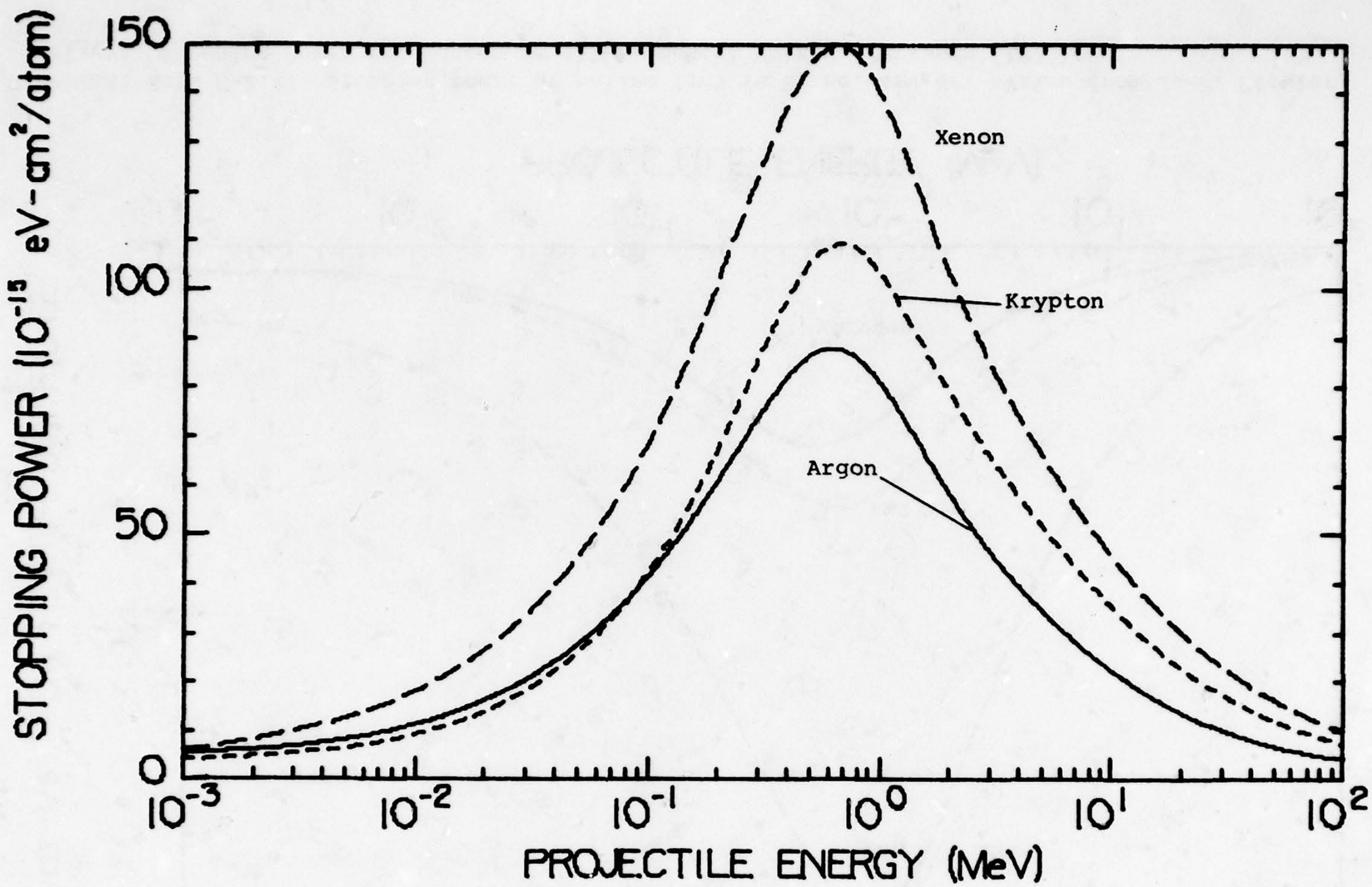
Tabular Data G-2.3. Stopping power of helium ions in F, Cl, Br, I, Cd, and U.

Units are: Energy in MeV; Stopping Power in 10^{-15} eV-cm^2/atom						
Energy	Gaseous Fluorine	Gaseous Chlorine	Gaseous Bromine	Gaseous Iodine	Solid Cadmium	Solid Uranium
0.001	5.18	6.28			5.78	6.65
0.002	5.64	7.41			7.66	9.48
0.004	6.57	9.33			10.3	13.4
0.007	7.77	11.8			13.3	17.8
0.010	8.79	13.9			15.9	21.5
0.015	10.2	16.9			19.7	26.6
0.020	11.5	19.6			23.0	31.1
0.030	13.6	24.2			28.9	38.9
0.050	16.9	31.9			38.8	51.8
0.075	20.2	39.7			48.9	65.0
0.100	22.9	46.3	41.6	70.6	57.6	76.4
0.150	27.4	57.1	54.3	89.0	71.8	95.6
0.200	30.9	65.5	65.0	104.	82.9	111.
0.300	36.3	77.4	81.7	125.	98.1	136.
0.500	42.7	87.4	99.3	145.	111.	165.
0.750	45.8	86.2	103.	146.	113.	178.
1.00	45.9	79.9	97.4	138.	110.	176.
1.50	42.1	66.8	84.6	119.	102.	158.
2.00	37.2	57.2	75.0	106.	94.4	141.
3.00	29.3	45.4	62.9	87.6	81.2	116.
5.00	20.8	33.4	49.6	67.3	63.3	89.8
7.50	15.7	25.8	40.2	53.2	49.9	72.1
10.0	12.9	21.2	34.2	44.4	41.5	61.0
15.0	9.59	16.0	26.5	34.8	32.4	48.9
20.0	7.73	13.0	21.9	29.0	26.9	41.4
30.0	5.65	9.60	16.5	22.2	20.5	32.2
50.0	3.78	6.48	11.4	15.5	14.3	23.0
75.0	2.73	4.72	8.46	11.6	10.7	17.4
100.0	2.17	3.77	6.81	9.41	8.63	14.3

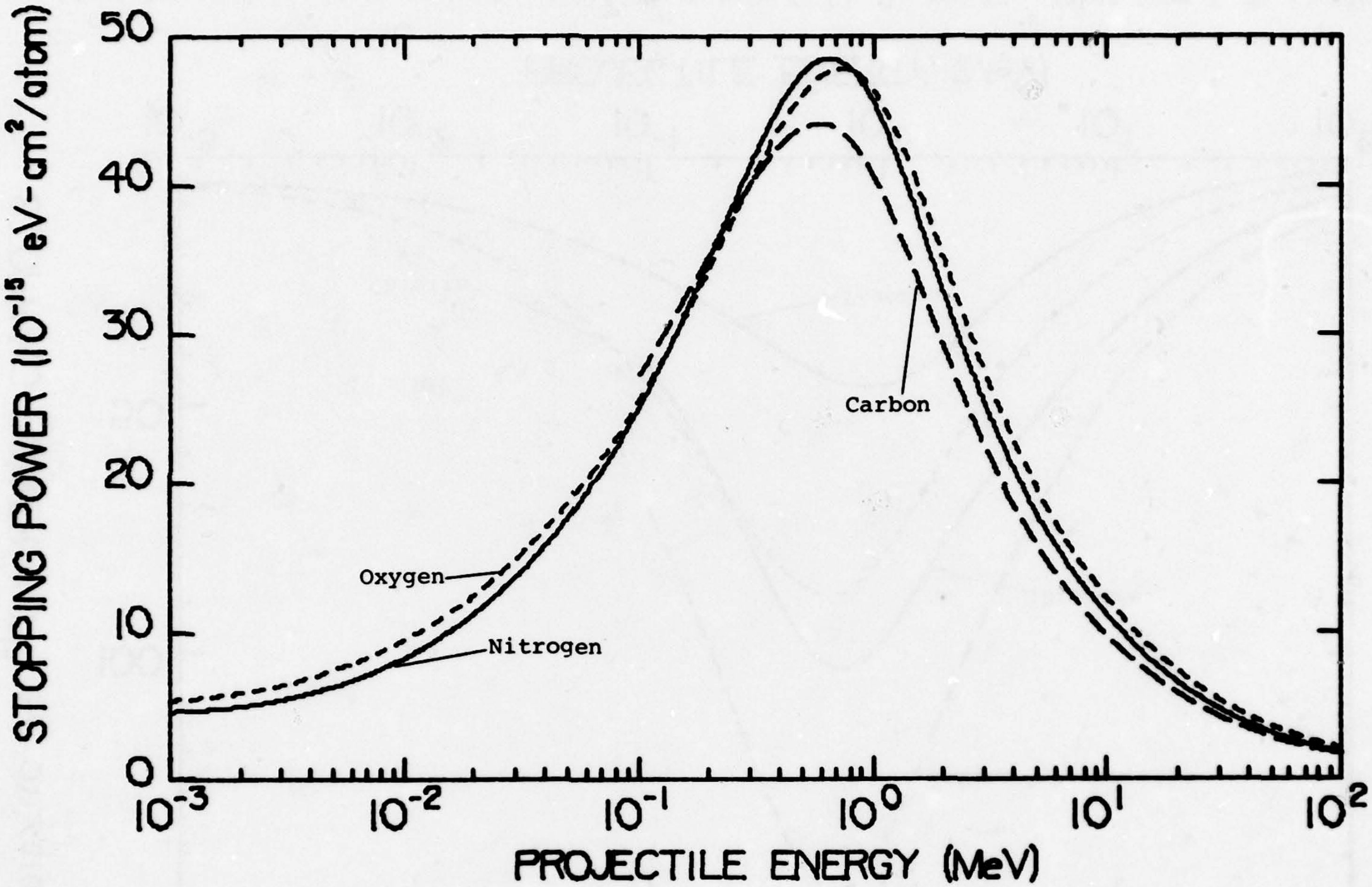
Reference: These data were taken from J. F. Ziegler, Helium: Stopping Power and Ranges in all Elemental Matter, Pergamon (1977).



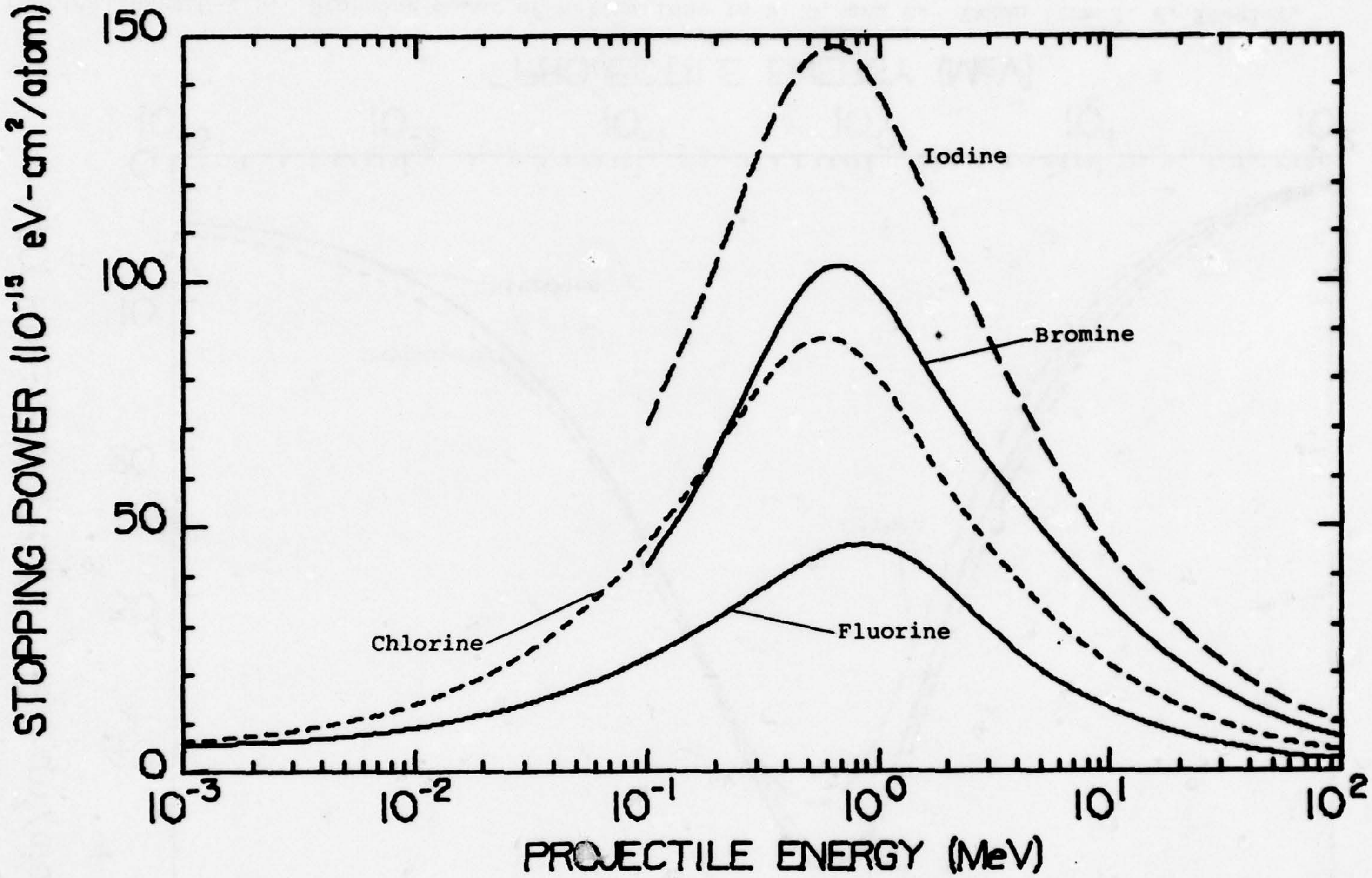
Graphical Data G-2.4. Stopping power of helium ions in H, He, and Ne. Taken from J. F. Ziegler, Helium: Stopping Power and Ranges in all Elemental Matter, Pergamon (1977).



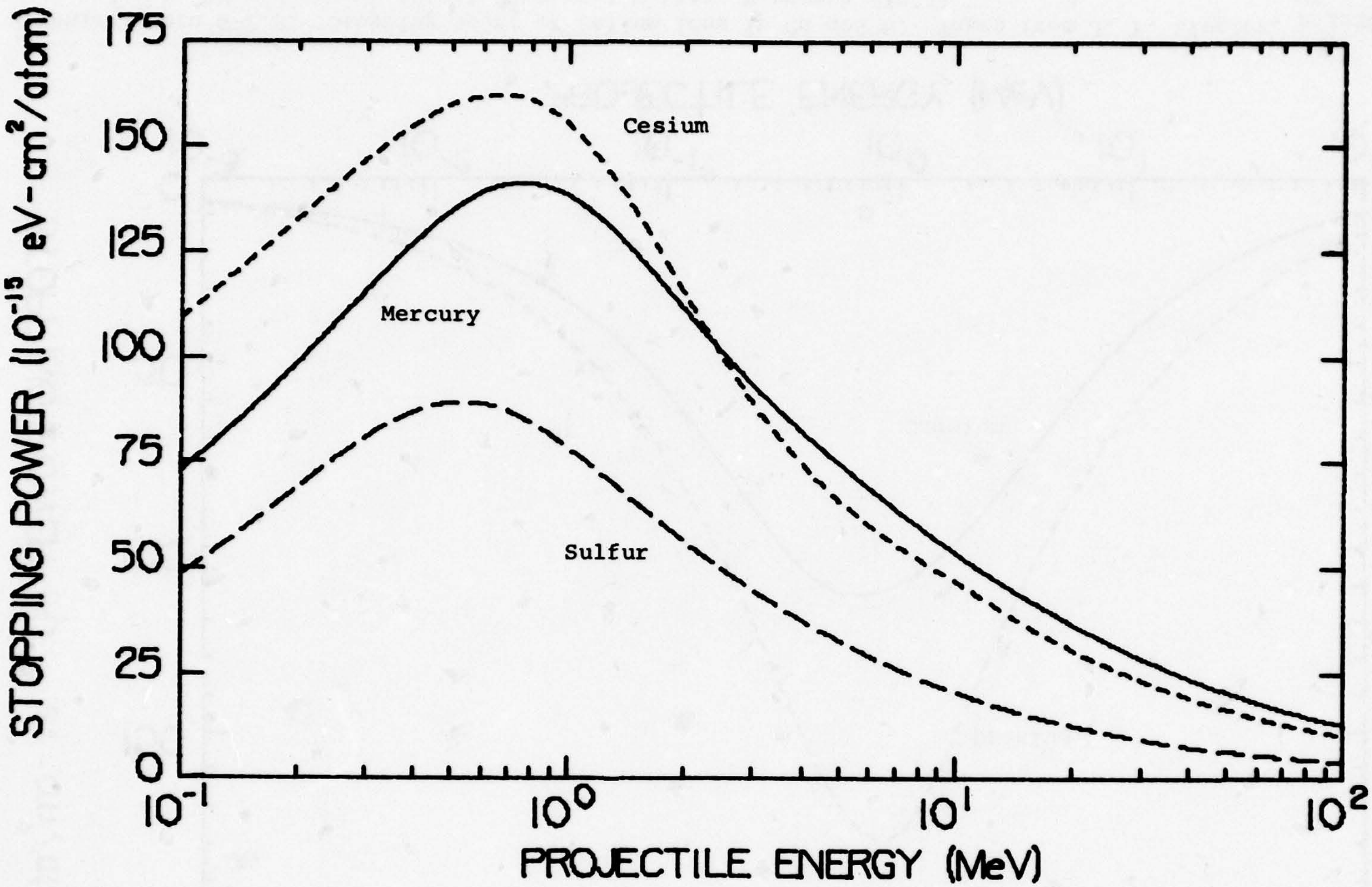
Graphical Data G-2.5. Stopping power of helium ions in Ar, Kr, and Xe. Taken from J. F. Ziegler, Helium: Stopping Power and Ranges in all Elemental Matter, Pergamon (1977).



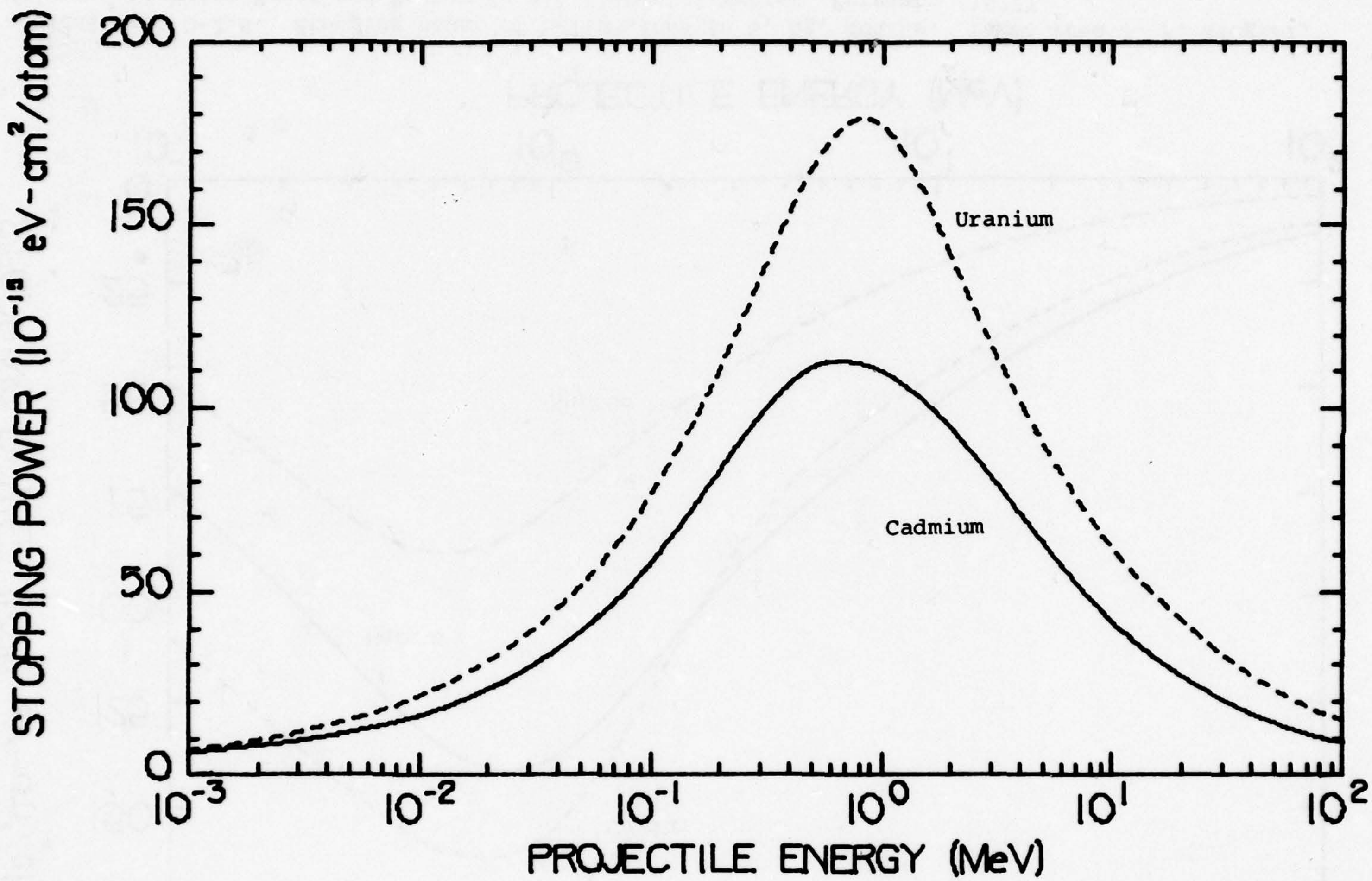
Graphical Data G-2.6. Stopping power of helium ions in N, O, and C. Taken from J. F. Ziegler, Helium: Stopping Power and Ranges in all Elemental Matter, Pergamon (1977).



Graphical Data G-2.7. Stopping power of helium ions in F, Cl, I, and Br. Taken from J. F. Ziegler, Helium: Stopping Power and Ranges in all Elemental Matter, Pergamon (1977).



Graphical Data G-2.8. Stopping power of helium ions in S, Hg, and Cs. Taken from J. F. Ziegler, Helium: Stopping Power and Ranges in all Elemental Matter, Pergamon (1977).



Graphical Data G-2.9. Stopping power of helium ions in Cd and U. Taken from J. F. Ziegler, Helium: Stopping Power and Ranges in all Elemental Matter, Pergamon (1977).

Tabular Data G-2.10. Range of helium ions in H_2, He, Ne, Ar, Kr, and Xe.

Units of energy are MeV, units of range are cm. The assumed gas density is N_L atoms/cm^3 for the rare gases, $2N_L$ atoms/cm^3 for hydrogen, where N_L is the Loschmidt Number, 2.688×10^{19}.

Energy	Hydrogen	Helium	Neon	Argon	Krypton	Xenon
0.001	0.009	0.015	0.004	0.002	0.002	0.001
0.002	0.020	0.031	0.008	0.005	0.003	0.002
0.004	0.041	0.063	0.016	0.010	0.006	0.004
0.007	0.073	0.108	0.027	0.017	0.011	0.006
0.010	0.101	0.149	0.038	0.024	0.016	0.009
0.015	0.141	0.208	0.055	0.035	0.024	0.014
0.020	0.176	0.259	0.070	0.044	0.032	0.018
0.030	0.234	0.346	0.097	0.060	0.046	0.025
0.050	0.321	0.482	0.143	0.086	0.068	0.038
0.075	0.402	0.614	0.191	0.111	0.090	0.051
0.100	0.468	0.722	0.233	0.132	0.109	0.063
0.150	0.578	0.903	0.306	0.167	0.140	0.082
0.200	0.672	1.06	0.369	0.198	0.166	0.099
0.300	0.840	1.33	0.481	0.251	0.211	0.130
0.500	1.15	1.81	0.675	0.348	0.289	0.185
0.750	1.54	2.38	0.898	0.466	0.382	0.251
1.00	1.95	2.97	1.12	0.585	0.474	0.319
1.50	2.87	4.21	1.56	0.841	0.668	0.464
2.00	3.92	5.61	2.03	1.13	0.880	0.624
3.00	6.54	8.91	3.09	1.79	1.36	0.993
4.00	9.92	13.0	4.35	2.60	1.94	1.44
5.00	14.2	18.1	5.83	3.57	2.60	1.95
6.00	19.4	24.2	7.57	4.72	3.37	2.55
8.00	33.2	40.0	11.9	7.57	5.21	3.99
10.00	52.3	61.6	17.7	11.3	7.50	5.79

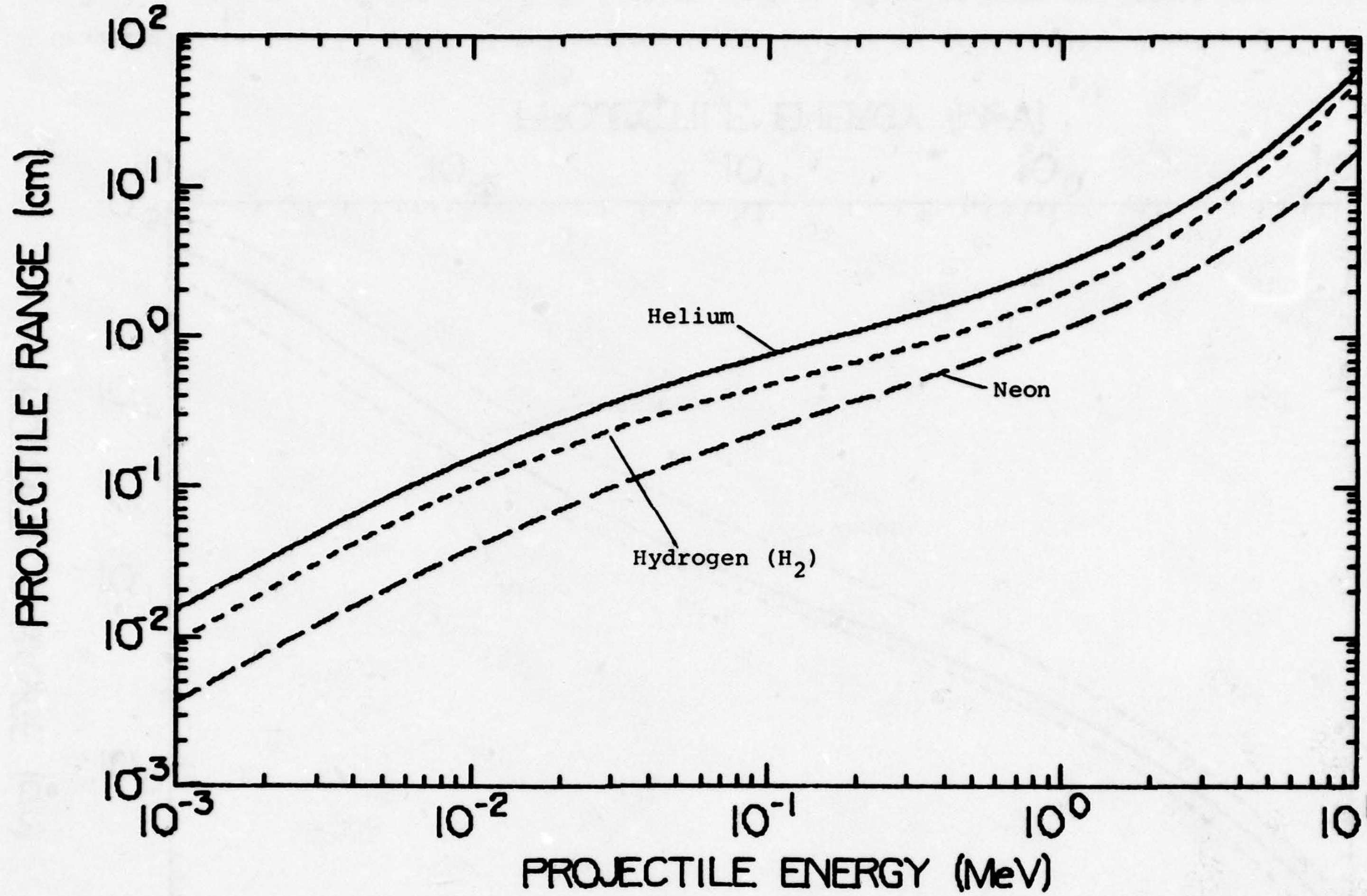
Reference: These data were taken from J. F. Ziegler, Helium: Stopping Power and Ranges in all Elemental Matter, Pergamon (1977).

Tabular Data G-2.11. Range of helium ions in N_2, O_2, F_2, and Cl_2.

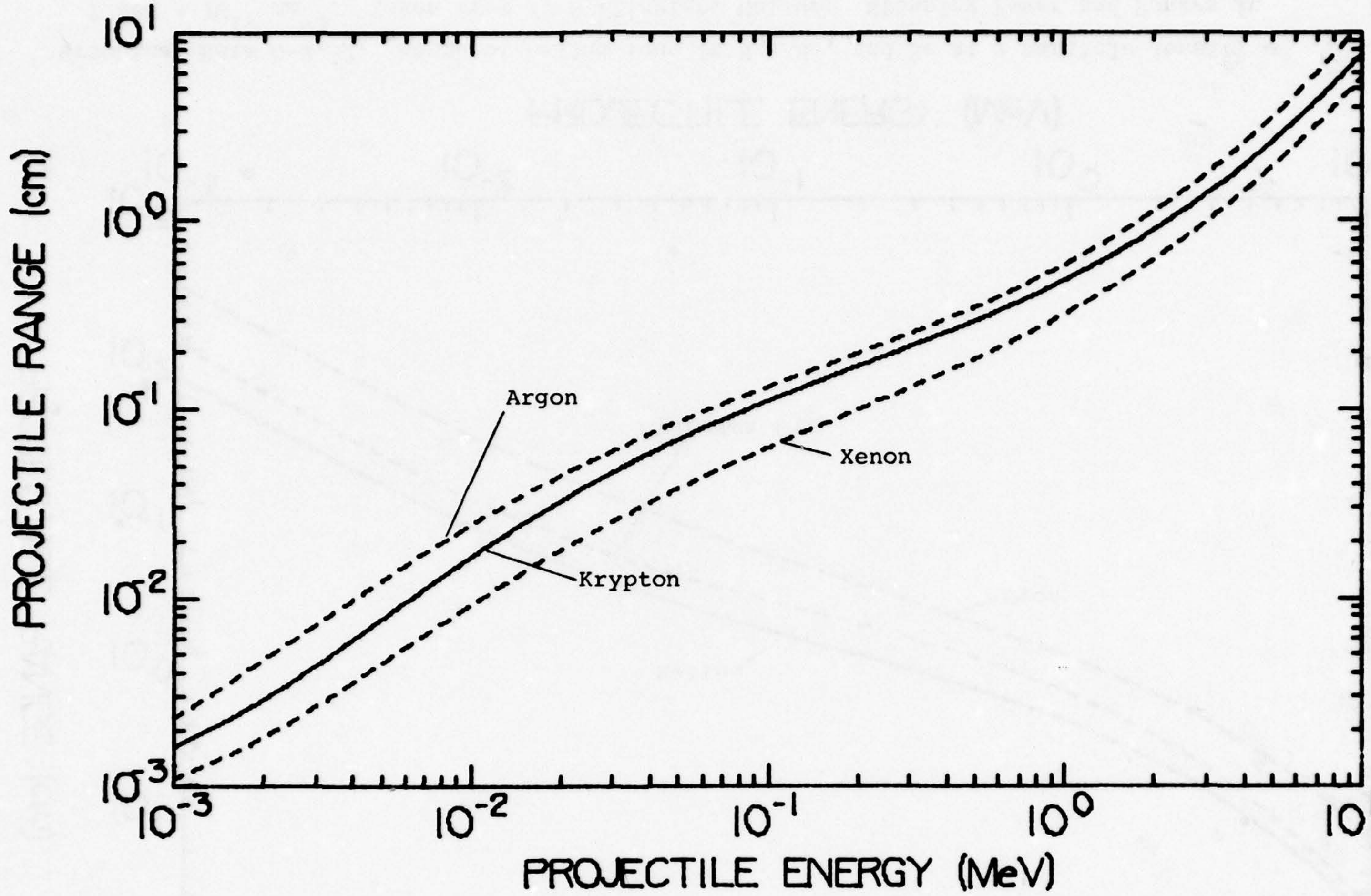
Units of energy are MeV, units of range are cm. The assumed gas density is $2N_L$ atoms/cm^3, where N_L is the Loschmidt Number: 2.688×10^{19}

Energy	Nitrogen	Oxygen	Fluorine	Chlorine
0.001	0.003	0.002	0.001	0.0006
0.002	0.005	0.004	0.002	0.001
0.004	0.010	0.008	0.004	0.002
0.007	0.017	0.014	0.007	0.004
0.010	0.023	0.019	0.010	0.006
0.015	0.032	0.027	0.014	0.008
0.020	0.040	0.034	0.017	0.010
0.030	0.054	0.047	0.024	0.013
0.050	0.076	0.067	0.035	0.019
0.075	0.098	0.088	0.046	0.025
0.100	0.116	0.106	0.056	0.029
0.150	0.147	0.137	0.074	0.037
0.200	0.175	0.164	0.089	0.044
0.300	0.223	0.213	0.115	0.057
0.500	0.311	0.301	0.162	0.081
0.750	0.416	0.406	0.217	0.110
1.00	0.524	0.512	0.270	0.140
1.50	0.753	0.735	0.380	0.204
2.00	1.01	0.980	0.499	0.276
3.00	1.62	1.55	0.770	0.447
4.00	2.36	2.25	1.10	0.656
5.00	3.27	3.09	1.48	0.906
6.00	4.36	4.08	1.95	1.20
8.00	7.16	6.64	3.13	1.94
10.00	10.9	10.1	4.71	2.89

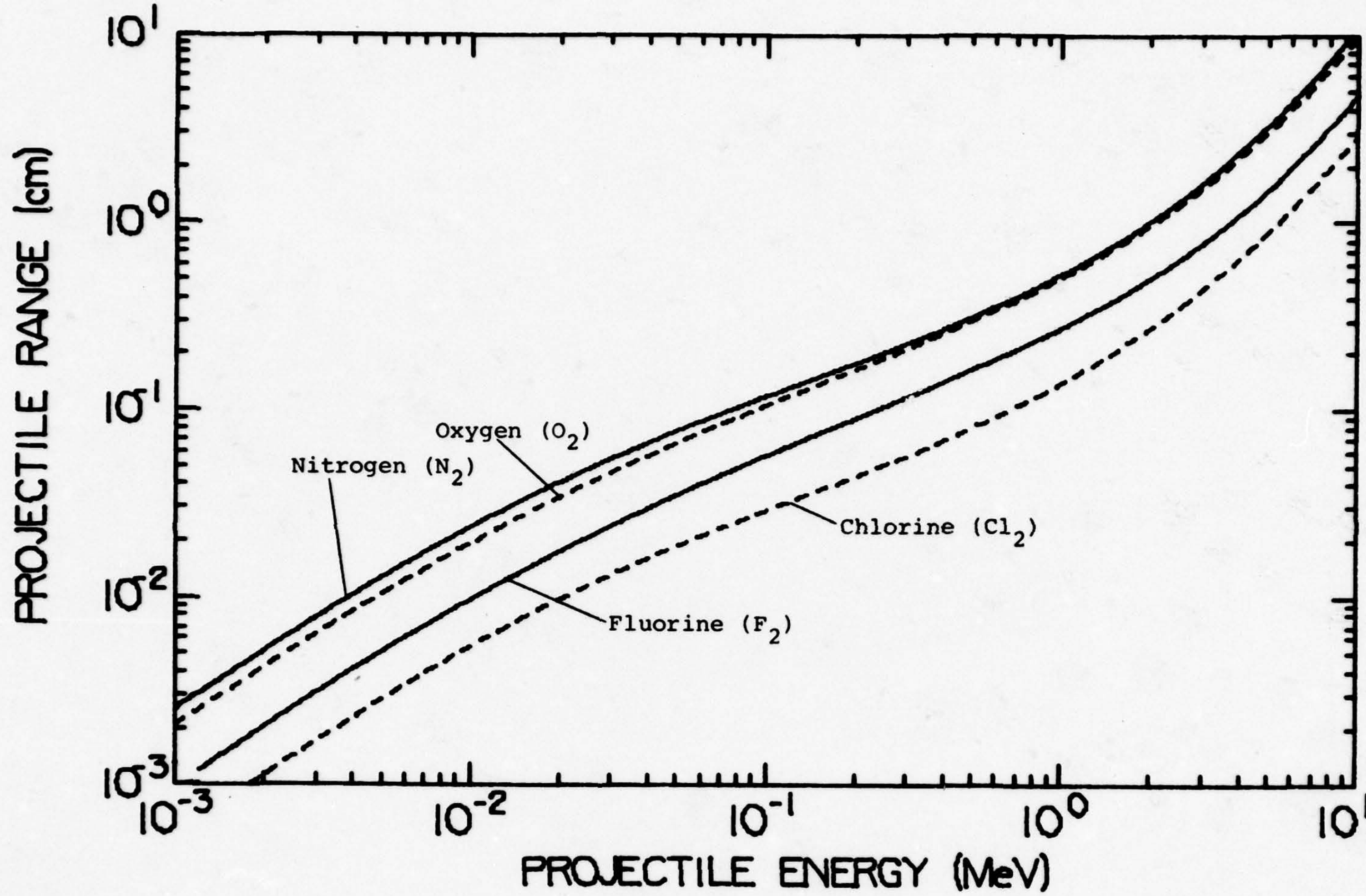
Reference: These data were taken from J. F. Ziegler, Helium: Stopping Power and Ranges in all Elemental Matter, Pergamon (1977).



Graphical Data G-2.12. Range of helium ions in H_2, He, and Ne at a particle density of 2.688×10^{19} cm^{-3}. Taken from J. F. Ziegler, Helium: Stopping Power and Ranges in all Elemental Matter, Pergamon (1977).



Graphical Data G-2.13. Range of helium ions in Ar, Kr, and Xe at a particle density of 2.688×10^{19} cm^{-3}. Taken from J. F. Ziegler, <u>Helium: Stopping Power and Ranges in all Elemental Matter</u>, Pergamon (1977).



Graphical Data G-2.14. Range of helium ions in N_2, O_2, F_2, and Cl_2 at a particle density of 2.688×10^{19} cm^{-3}. Taken from J. F. Ziegler, Helium: Stopping Power and Ranges in all Elemental Matter, Pergamon (1977).

G-3. STOPPING POWER OF HEAVY IONS IN GASES

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G-3.23. Stopping power of heavy ions in atomic nitrogen 2191

G-3.24. Stopping power of heavy ions in atomic nitrogen 2192

G-3.25. Stopping power of heavy ions in atomic oxygen 2193

G-3.26. Stopping power of heavy ions in atomic oxygen 2194

G-3.27. Stopping power of heavy ions in atomic sulfur 2195

G-3.28. Stopping power of heavy ions in atomic sulfur 2196

G-3.29. Stopping power of heavy ions in atomic cadmium 2197

G-3.30. Stopping power of heavy ions in atomic cadmium 2198

G-3.31. Stopping power of heavy ions in atomic cesium 2199

G-3.32. Stopping power of heavy ions in atomic cesium 2200

G-3.33. Stopping power of heavy ions in atomic mercury 2201

G-3.34. Stopping power of heavy ions in atomic mercury 2202

G-3.35. Stopping power of heavy ions in atomic uranium 2203

G-3.36. Stopping power of heavy ions in atomic uranium 2204

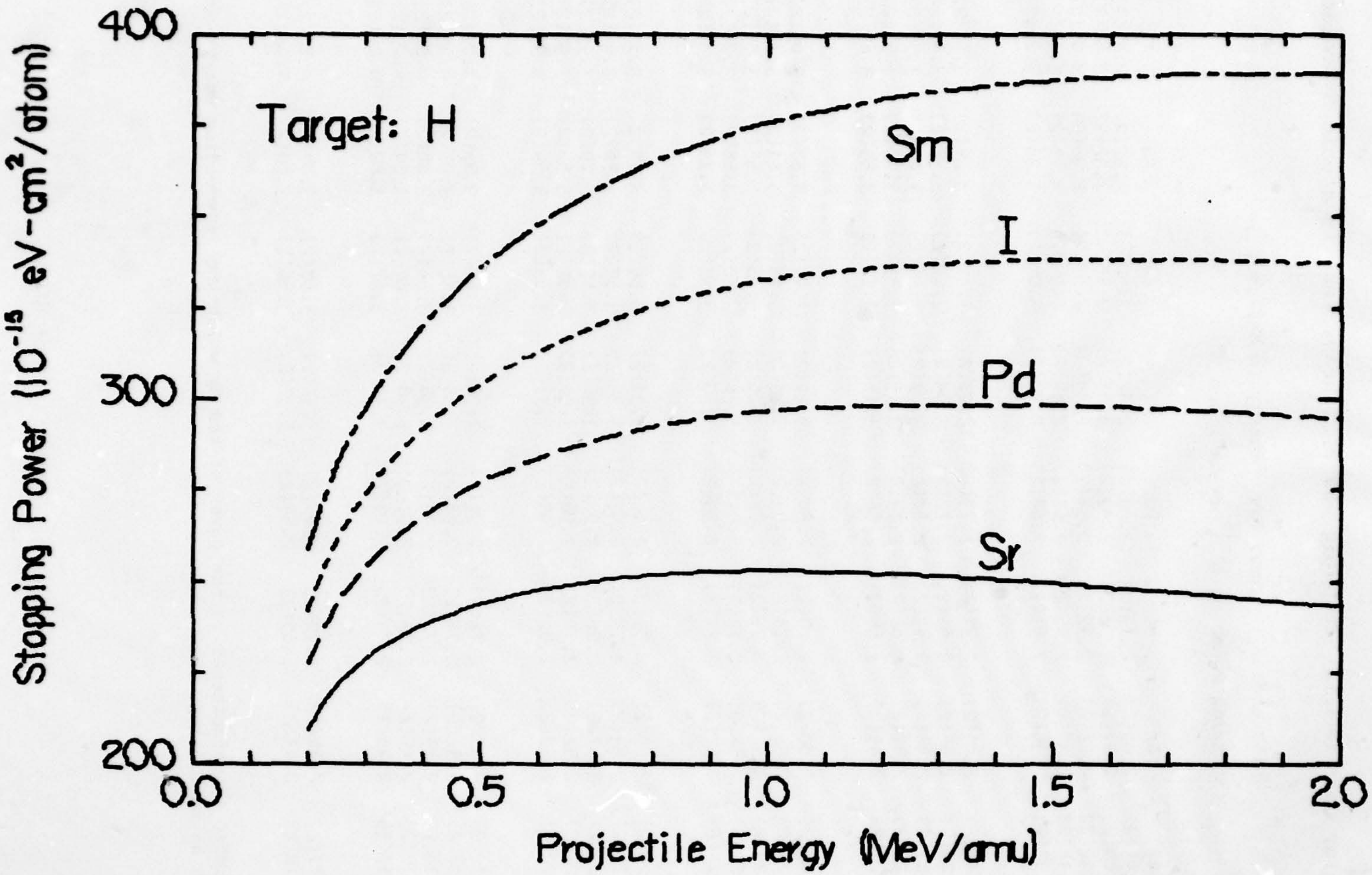
Tabular Data G-3.1. Stopping power of heavy ions in atomic hydrogen.

Units are: Heavy Ion Energy in MeV/amu,

Stopping Power in 10^{-15} eV-cm^2/atom

E	As *	Sr	Mo	Pd	I	Ce	Sm	Tb
.20	1.95(2)	2.09(2)	2.19(2)	2.28(2)	2.42(2)	2.52(2)	2.59(2)	2.64(2)
.25	2.05(2)	2.21(2)	2.32(2)	2.43(2)	2.61(2)	2.73(2)	2.82(2)	2.88(2)
.30	2.10(2)	2.28(2)	2.42(2)	2.54(2)	2.74(2)	2.88(2)	2.98(2)	3.05(2)
.35	2.14(2)	2.34(2)	2.48(2)	2.62(2)	2.84(2)	2.99(2)	3.10(2)	3.18(2)
.40	2.17(2)	2.38(2)	2.53(2)	2.68(2)	2.92(2)	3.08(2)	3.20(2)	3.29(2)
.45	2.19(2)	2.41(2)	2.57(2)	2.73(2)	2.98(2)	3.16(2)	3.29(2)	3.38(2)
.50	2.20(2)	2.43(2)	2.61(2)	2.77(2)	3.04(2)	3.22(2)	3.36(2)	3.46(2)
.55	2.21(2)	2.45(2)	2.63(2)	2.81(2)	3.09(2)	3.28(2)	3.42(2)	3.53(2)
.60	2.22(2)	2.47(2)	2.66(2)	2.84(2)	3.13(2)	3.33(2)	3.48(2)	3.59(2)
.65	2.23(2)	2.49(2)	2.68(2)	2.86(2)	3.17(2)	3.37(2)	3.53(2)	3.64(2)
.70	2.24(2)	2.50(2)	2.70(2)	2.89(2)	3.20(2)	3.41(2)	3.57(2)	3.69(2)
.75	2.24(2)	2.51(2)	2.71(2)	2.91(2)	3.23(2)	3.45(2)	3.61(2)	3.74(2)
.80	2.24(2)	2.52(2)	2.72(2)	2.92(2)	3.25(2)	3.48(2)	3.65(2)	3.78(2)
.85	2.24(2)	2.52(2)	2.73(2)	2.94(2)	3.28(2)	3.50(2)	3.68(2)	3.81(2)
.90	2.24(2)	2.53(2)	2.74(2)	2.95(2)	3.30(2)	3.53(2)	3.71(2)	3.84(2)
.95	2.24(2)	2.53(2)	2.75(2)	2.96(2)	3.31(2)	3.55(2)	3.74(2)	3.87(2)
1.00	2.24(2)	2.53(2)	2.75(2)	2.97(2)	3.33(2)	3.57(2)	3.76(2)	3.90(2)
1.10	2.23(2)	2.53(2)	2.76(2)	2.98(2)	3.35(2)	3.60(2)	3.79(2)	3.93(2)
1.20	2.22(2)	2.52(2)	2.76(2)	2.98(2)	3.36(2)	3.62(2)	3.82(2)	3.97(2)
1.30	2.20(2)	2.52(2)	2.76(2)	2.99(2)	3.37(2)	3.64(2)	3.84(2)	3.99(2)
1.40	2.19(2)	2.51(2)	2.75(2)	2.99(2)	3.38(2)	3.65(2)	3.86(2)	4.01(2)
1.50	2.18(2)	2.50(2)	2.74(2)	2.98(2)	3.38(2)	3.66(2)	3.87(2)	4.03(2)
1.60	2.16(2)	2.49(2)	2.73(2)	2.98(2)	3.38(2)	3.66(2)	3.88(2)	4.04(2)
1.70	2.15(2)	2.47(2)	2.72(2)	2.97(2)	3.38(2)	3.67(2)	3.89(2)	4.05(2)
1.80	2.13(2)	2.46(2)	2.71(2)	2.96(2)	3.38(2)	3.67(2)	3.89(2)	4.06(2)
1.90	2.11(2)	2.45(2)	2.70(2)	2.95(2)	3.37(2)	3.67(2)	3.89(2)	4.06(2)
2.00	2.10(2)	2.43(2)	2.69(2)	2.94(2)	3.37(2)	3.66(2)	3.89(2)	4.06(2)

* The number in parentheses is the power of ten by which the preceeding entry is to be multiplied.



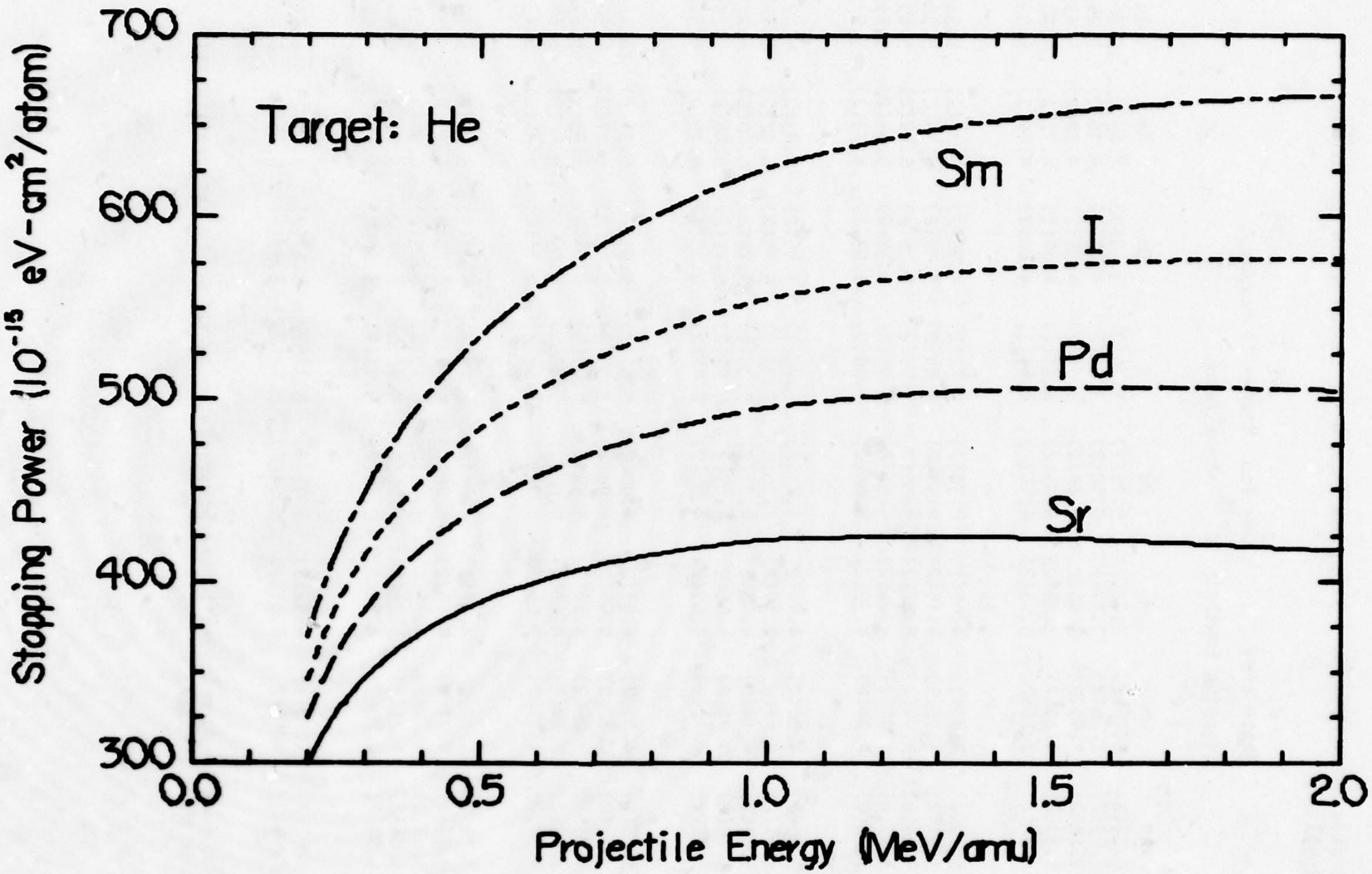
Graphical Data G-3.2. Stopping power of heavy ions in atomic hydrogen.

Tabular Data G-3.3. Stopping power of heavy ions in atomic helium.

Units are: Heavy Ion Energy in MeV/amu,
Stopping Power in 10^{-15} eV-cm^2/atom

E	As*	Sr	Mo	Pd	I	Ce	Sm	Tb
.20	2.79(2)	2.98(2)	3.12(2)	3.25(2)	3.46(2)	3.59(2)	3.69(2)	3.76(2)
.25	3.03(2)	3.26(2)	3.44(2)	3.60(2)	3.86(2)	4.03(2)	4.16(2)	4.25(2)
.30	3.18(2)	3.46(2)	3.66(2)	3.84(2)	4.15(2)	4.35(2)	4.50(2)	4.61(2)
.35	3.30(2)	3.60(2)	3.82(2)	4.03(2)	4.37(2)	4.60(2)	4.77(2)	4.90(2)
.40	3.38(2)	3.71(2)	3.95(2)	4.18(2)	4.55(2)	4.80(2)	4.99(2)	5.13(2)
.45	3.45(2)	3.80(2)	4.06(2)	4.30(2)	4.71(2)	4.98(2)	5.18(2)	5.33(2)
.50	3.51(2)	3.87(2)	4.15(2)	4.41(2)	4.84(2)	5.12(2)	5.34(2)	5.50(2)
.55	3.55(2)	3.94(2)	4.22(2)	4.50(2)	4.95(2)	5.25(2)	5.49(2)	5.65(2)
.60	3.59(2)	3.99(2)	4.29(2)	4.58(2)	5.05(2)	5.37(2)	5.61(2)	5.79(2)
.65	3.62(2)	4.04(2)	4.35(2)	4.65(2)	5.14(2)	5.47(2)	5.73(2)	5.91(2)
.70	3.65(2)	4.08(2)	4.40(2)	4.71(2)	5.22(2)	5.56(2)	5.83(2)	6.02(2)
.75	3.67(2)	4.11(2)	4.44(2)	4.76(2)	5.29(2)	5.65(2)	5.92(2)	6.12(2)
.80	3.69(2)	4.14(2)	4.48(2)	4.81(2)	5.35(2)	5.72(2)	6.00(2)	6.21(2)
.85	3.70(2)	4.17(2)	4.52(2)	4.85(2)	5.41(2)	5.79(2)	6.08(2)	6.29(2)
.90	3.72(2)	4.19(2)	4.55(2)	4.89(2)	5.46(2)	5.85(2)	6.15(2)	6.37(2)
.95	3.73(2)	4.21(2)	4.57(2)	4.92(2)	5.51(2)	5.91(2)	6.21(2)	6.44(2)
1.00	3.73(2)	4.22(2)	4.60(2)	4.95(2)	5.55(2)	5.96(2)	6.27(2)	6.50(2)
1.10	3.73(2)	4.24(2)	4.62(2)	4.99(2)	5.61(2)	6.03(2)	6.35(2)	6.59(2)
1.20	3.73(2)	4.24(2)	4.64(2)	5.02(2)	5.65(2)	6.09(2)	6.42(2)	6.67(2)
1.30	3.72(2)	4.25(2)	4.65(2)	5.04(2)	5.69(2)	6.14(2)	6.48(2)	6.73(2)
1.40	3.71(2)	4.24(2)	4.65(2)	5.05(2)	5.72(2)	6.17(2)	6.53(2)	6.79(2)
1.50	3.69(2)	4.23(2)	4.65(2)	5.06(2)	5.74(2)	6.20(2)	6.57(2)	6.83(2)
1.60	3.67(2)	4.22(2)	4.65(2)	5.06(2)	5.75(2)	6.23(2)	6.60(2)	6.87(2)
1.70	3.66(2)	4.21(2)	4.64(2)	5.06(2)	5.76(2)	6.24(2)	6.62(2)	6.90(2)
1.80	3.64(2)	4.20(2)	4.63(2)	5.05(2)	5.77(2)	6.26(2)	6.64(2)	6.92(2)
1.90	3.61(2)	4.18(2)	4.62(2)	5.05(2)	5.77(2)	6.27(2)	6.65(2)	6.94(2)
2.00	3.59(2)	4.16(2)	4.61(2)	5.04(2)	5.77(2)	6.27(2)	6.66(2)	6.95(2)

* The number in parentheses is the power of ten by which the preceeding entry is to be multiplied.



Graphical Data G-3.4. Stopping power of heavy ions in atomic helium.

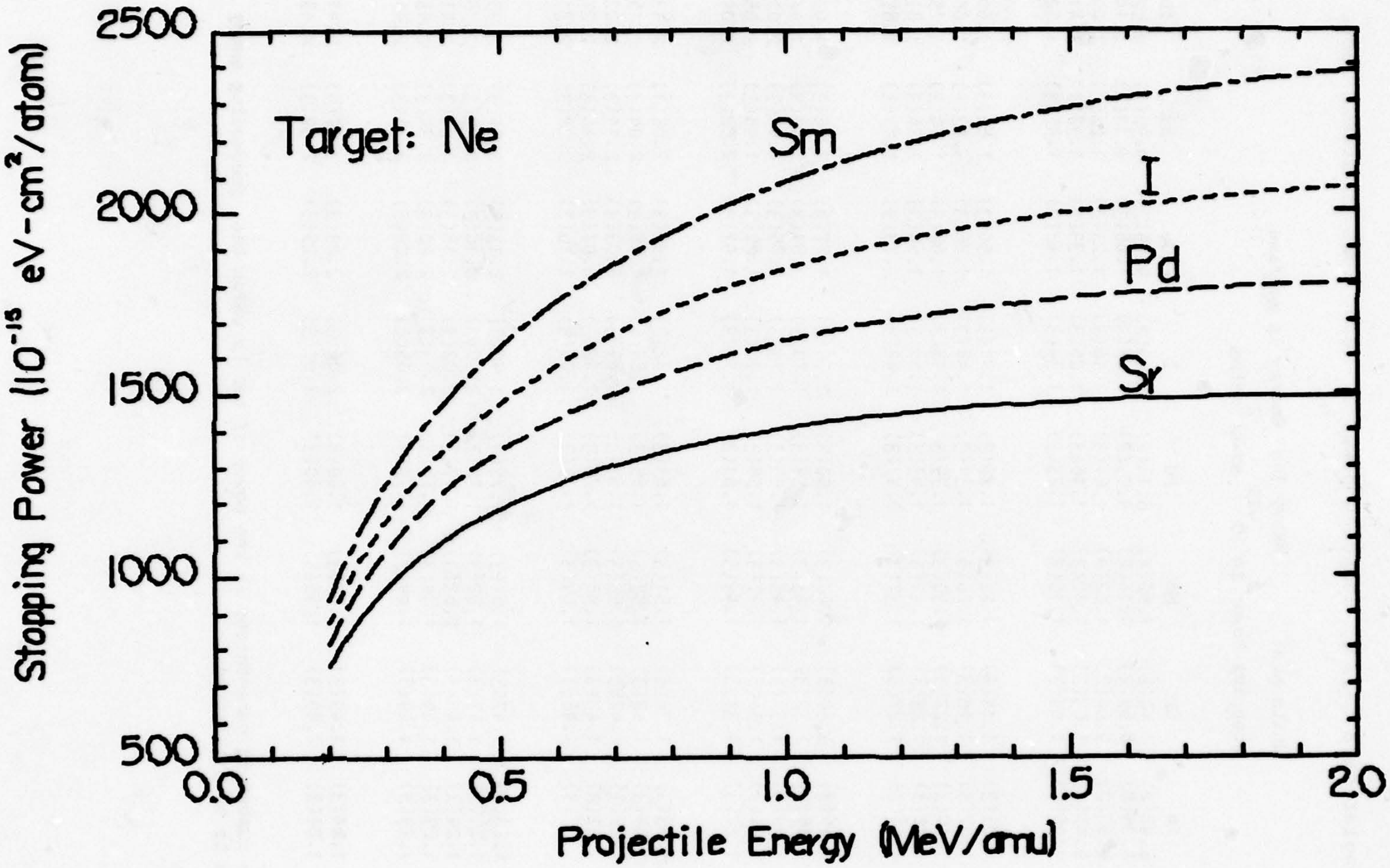
Tabular Data G-3.5. Stopping power of heavy ions in atomic neon.

Units are: Heavy Ion Energy in MeV/amu,

Stopping Power in 10^{-15} eV-cm^2/atom

E	As*	Sr	Mo	Pd	I	Ce	Sm	Tb
.20	6.97(2)	7.46(2)	7.82(2)	8.16(2)	8.70(2)	9.05(2)	9.32(2)	9.52(2)
.25	8.05(2)	8.69(2)	9.16(2)	9.59(2)	1.03(3)	1.08(3)	1.11(3)	1.14(3)
.30	8.85(2)	9.62(2)	1.02(3)	1.07(3)	1.16(3)	1.21(3)	1.26(3)	1.29(3)
.35	9.47(2)	1.03(3)	1.10(3)	1.16(3)	1.26(3)	1.33(3)	1.38(3)	1.41(3)
.40	9.95(2)	1.09(3)	1.16(3)	1.23(3)	1.34(3)	1.42(3)	1.47(3)	1.52(3)
.45	1.03(3)	1.14(3)	1.22(3)	1.29(3)	1.41(3)	1.50(3)	1.56(3)	1.60(3)
.50	1.07(3)	1.18(3)	1.26(3)	1.34(3)	1.48(3)	1.56(3)	1.63(3)	1.68(3)
.55	1.10(3)	1.22(3)	1.30(3)	1.39(3)	1.53(3)	1.62(3)	1.70(3)	1.75(3)
.60	1.12(3)	1.25(3)	1.34(3)	1.43(3)	1.58(3)	1.68(3)	1.76(3)	1.81(3)
.65	1.14(3)	1.27(3)	1.37(3)	1.47(3)	1.62(3)	1.73(3)	1.81(3)	1.87(3)
.70	1.16(3)	1.30(3)	1.40(3)	1.50(3)	1.66(3)	1.77(3)	1.86(3)	1.92(3)
.75	1.18(3)	1.32(3)	1.43(3)	1.53(3)	1.70(3)	1.81(3)	1.90(3)	1.97(3)
.80	1.19(3)	1.34(3)	1.45(3)	1.56(3)	1.73(3)	1.85(3)	1.94(3)	2.01(3)
.85	1.21(3)	1.36(3)	1.47(3)	1.58(3)	1.76(3)	1.89(3)	1.98(3)	2.05(3)
.90	1.22(3)	1.37(3)	1.49(3)	1.61(3)	1.79(3)	1.92(3)	2.02(3)	2.09(3)
.95	1.23(3)	1.39(3)	1.51(3)	1.63(3)	1.82(3)	1.95(3)	2.05(3)	2.13(3)
1.00	1.24(3)	1.40(3)	1.53(3)	1.65(3)	1.84(3)	1.98(3)	2.08(3)	2.16(3)
1.10	1.25(3)	1.42(3)	1.55(3)	1.68(3)	1.89(3)	2.03(3)	2.14(3)	2.22(3)
1.20	1.27(3)	1.44(3)	1.58(3)	1.70(3)	1.92(3)	2.07(3)	2.18(3)	2.27(3)
1.30	1.27(3)	1.46(3)	1.59(3)	1.73(3)	1.95(3)	2.10(3)	2.22(3)	2.31(3)
1.40	1.28(3)	1.47(3)	1.61(3)	1.75(3)	1.98(3)	2.13(3)	2.26(3)	2.35(3)
1.50	1.29(3)	1.47(3)	1.62(3)	1.76(3)	2.00(3)	2.16(3)	2.29(3)	2.38(3)
1.60	1.29(3)	1.48(3)	1.63(3)	1.77(3)	2.02(3)	2.18(3)	2.31(3)	2.41(3)
1.70	1.29(3)	1.49(3)	1.64(3)	1.78(3)	2.03(3)	2.20(3)	2.34(3)	2.43(3)
1.80	1.29(3)	1.49(3)	1.64(3)	1.79(3)	2.05(3)	2.22(3)	2.36(3)	2.45(3)
1.90	1.29(3)	1.49(3)	1.65(3)	1.80(3)	2.06(3)	2.23(3)	2.37(3)	2.47(3)
2.00	1.29(3)	1.49(3)	1.65(3)	1.80(3)	2.07(3)	2.25(3)	2.39(3)	2.49(3)

* The number in parentheses is the power of ten by which the preceeding entry is to be multiplied.



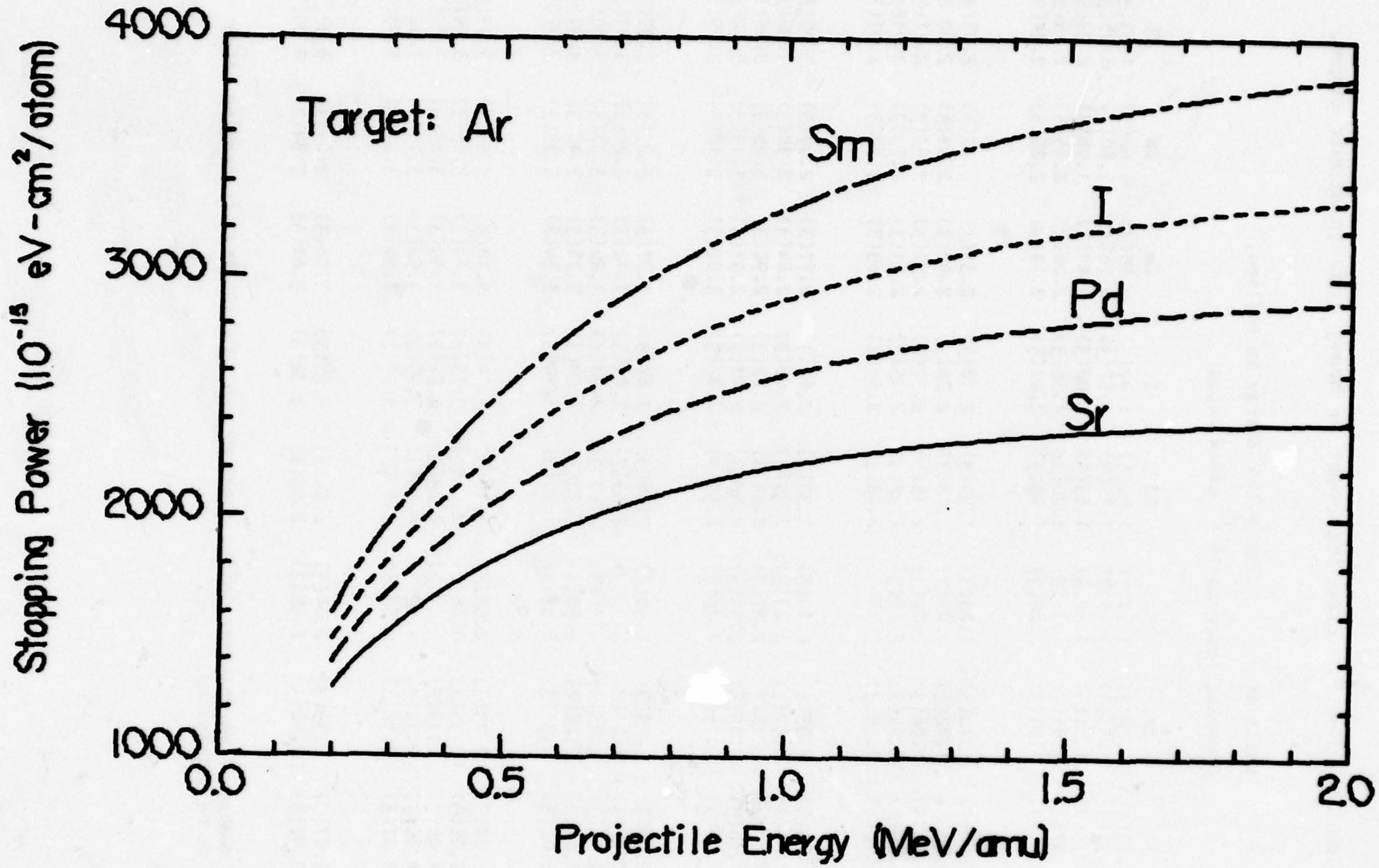
Graphical Data G-3.6. Stopping power of heavy ions in atomic neon.

Tabular Data G-3.7. Stopping power of heavy ions in atomic argon.

Units are: Heavy Ion Energy in MeV/amu,
Stopping Power in 10^{-15} eV-cm^2/atom

E	As	Sr	Mo	Pd	I	Ce	Sm	Tb
.20	1.19(3)*	1.28(3)	1.34(3)	1.40(3)	1.49(3)	1.55(3)	1.60(3)	1.63(3)
.25	1.30(3)	1.41(3)	1.48(3)	1.55(3)	1.67(3)	1.75(3)	1.80(3)	1.85(3)
.30	1.39(3)	1.51(3)	1.60(3)	1.69(3)	1.82(3)	1.91(3)	1.98(3)	2.03(3)
.35	1.47(3)	1.61(3)	1.71(3)	1.80(3)	1.96(3)	2.06(3)	2.14(3)	2.19(3)
.40	1.54(3)	1.69(3)	1.80(3)	1.90(3)	2.07(3)	2.19(3)	2.28(3)	2.34(3)
.45	1.60(3)	1.76(3)	1.88(3)	1.99(3)	2.18(3)	2.31(3)	2.40(3)	2.47(3)
.50	1.65(3)	1.82(3)	1.95(3)	2.08(3)	2.28(3)	2.42(3)	2.52(3)	2.60(3)
.55	1.70(3)	1.88(3)	2.02(3)	2.15(3)	2.37(3)	2.52(3)	2.63(3)	2.71(3)
.60	1.74(3)	1.94(3)	2.08(3)	2.22(3)	2.45(3)	2.61(3)	2.73(3)	2.81(3)
.65	1.78(3)	1.98(3)	2.14(3)	2.28(3)	2.53(3)	2.69(3)	2.82(3)	2.91(3)
.70	1.81(3)	2.03(3)	2.19(3)	2.34(3)	2.60(3)	2.77(3)	2.90(3)	3.00(3)
.75	1.84(3)	2.07(3)	2.23(3)	2.39(3)	2.66(3)	2.84(3)	2.98(3)	3.08(3)
.80	1.87(3)	2.10(3)	2.27(3)	2.44(3)	2.72(3)	2.90(3)	3.05(3)	3.15(3)
.85	1.90(3)	2.13(3)	2.31(3)	2.48(3)	2.77(3)	2.97(3)	3.11(3)	3.22(3)
.90	1.92(3)	2.16(3)	2.35(3)	2.52(3)	2.82(3)	3.02(3)	3.18(3)	3.29(3)
.95	1.94(3)	2.19(3)	2.38(3)	2.56(3)	2.87(3)	3.07(3)	3.23(3)	3.35(3)
1.00	1.96(3)	2.21(3)	2.41(3)	2.59(3)	2.91(3)	3.12(3)	3.29(3)	3.41(3)
1.10	1.98(3)	2.25(3)	2.45(3)	2.65(3)	2.98(3)	3.20(3)	3.38(3)	3.50(3)
1.20	2.01(3)	2.28(3)	2.50(3)	2.70(3)	3.04(3)	3.28(3)	3.46(3)	3.59(3)
1.30	2.02(3)	2.31(3)	2.53(3)	2.74(3)	3.10(3)	3.34(3)	3.53(3)	3.67(3)
1.40	2.04(3)	2.33(3)	2.56(3)	2.78(3)	3.14(3)	3.40(3)	3.59(3)	3.73(3)
1.50	2.05(3)	2.35(3)	2.58(3)	2.81(3)	3.19(3)	3.44(3)	3.65(3)	3.79(3)
1.60	2.06(3)	2.36(3)	2.60(3)	2.83(3)	3.22(3)	3.49(3)	3.69(3)	3.85(3)
1.70	2.06(3)	2.38(3)	2.62(3)	2.85(3)	3.25(3)	3.52(3)	3.74(3)	3.89(3)
1.80	2.07(3)	2.38(3)	2.63(3)	2.87(3)	3.28(3)	3.56(3)	3.77(3)	3.93(3)
1.90	2.07(3)	2.39(3)	2.64(3)	2.89(3)	3.30(3)	3.58(3)	3.81(3)	3.97(3)
2.00	2.07(3)	2.40(3)	2.65(3)	2.90(3)	3.32(3)	3.61(3)	3.84(3)	4.00(3)

* The number in parentheses is the power of ten by which the preceeding entry is to be multiplied.



Graphical Data G-3.8. Stopping power of heavy ions in atomic argon.

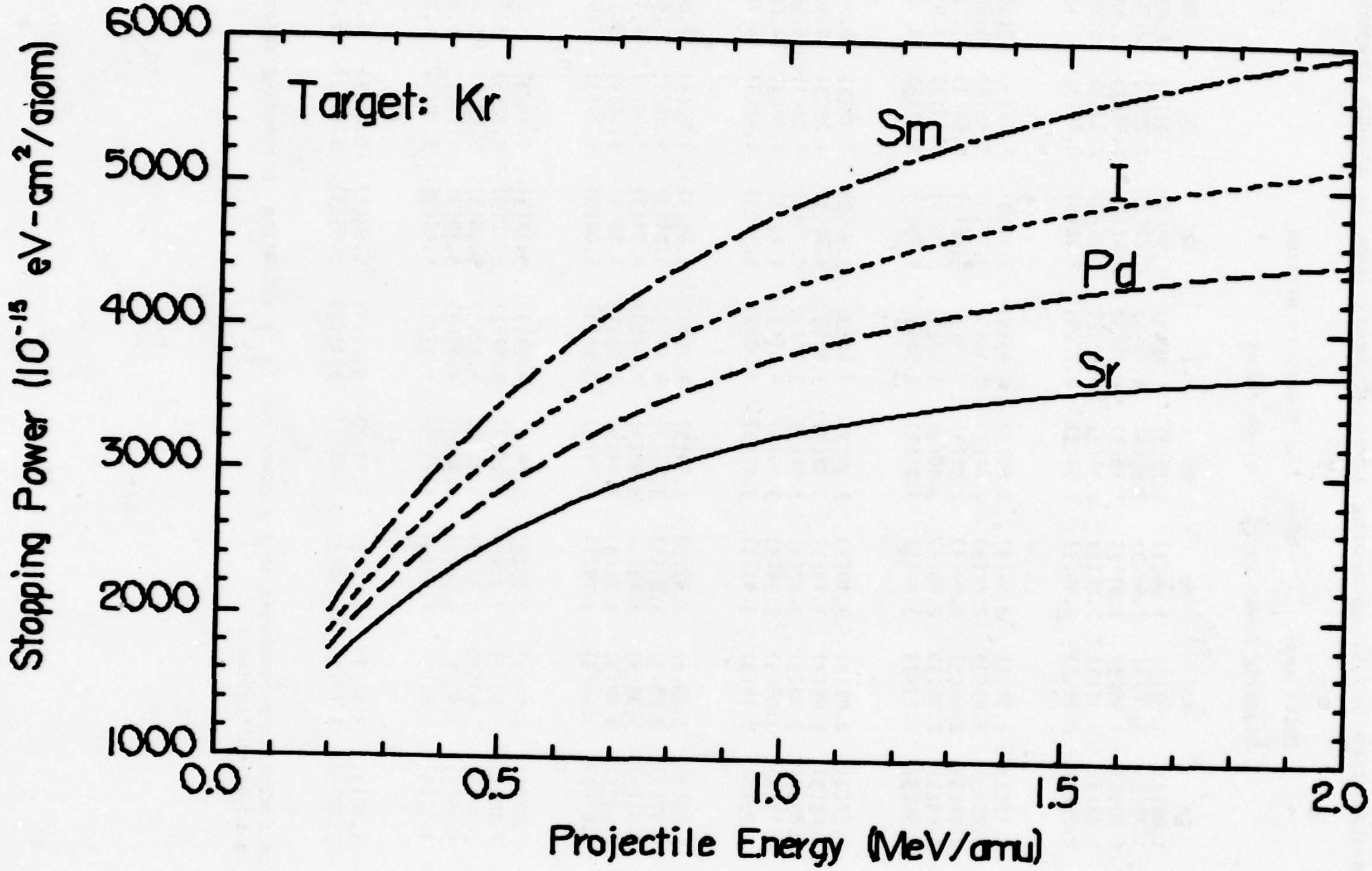
Tabular Data G-3.9. Stopping power of heavy ions in atomic krypton.

Units are: Heavy Ion Energy in MeV/amu,

Stopping Power in 10^{-15} $eV\text{-}cm^2/atom$

E	As *	Sr	Mo	Pd	I	Ce	Sm	Tb
.20	1.48(3)	1.58(3)	1.66(3)	1.73(3)	1.85(3)	1.93(3)	1.99(3)	2.03(3)
.25	1.65(3)	1.78(3)	1.88(3)	1.97(3)	2.12(3)	2.22(3)	2.29(3)	2.35(3)
.30	1.80(3)	1.95(3)	2.07(3)	2.18(3)	2.36(3)	2.47(3)	2.56(3)	2.63(3)
.35	1.93(3)	2.11(3)	2.24(3)	2.36(3)	2.57(3)	2.71(3)	2.81(3)	2.89(3)
.40	2.05(3)	2.25(3)	2.40(3)	2.54(3)	2.77(3)	2.92(3)	3.04(3)	3.13(3)
.45	2.16(3)	2.38(3)	2.54(3)	2.69(3)	2.95(3)	3.12(3)	3.25(3)	3.35(3)
.50	2.25(3)	2.49(3)	2.67(3)	2.84(3)	3.12(3)	3.31(3)	3.45(3)	3.56(3)
.55	2.34(3)	2.60(3)	2.79(3)	2.97(3)	3.28(3)	3.48(3)	3.64(3)	3.75(3)
.60	2.43(3)	2.70(3)	2.90(3)	3.10(3)	3.42(3)	3.64(3)	3.81(3)	3.93(3)
.65	2.50(3)	2.79(3)	3.01(3)	3.21(3)	3.56(3)	3.79(3)	3.97(3)	4.10(3)
.70	2.57(3)	2.87(3)	3.10(3)	3.32(3)	3.68(3)	3.93(3)	4.12(3)	4.25(3)
.75	2.63(3)	2.95(3)	3.19(3)	3.42(3)	3.80(3)	4.06(3)	4.25(3)	4.40(3)
.80	2.69(3)	3.02(3)	3.27(3)	3.51(3)	3.91(3)	4.18(3)	4.38(3)	4.53(3)
.85	2.74(3)	3.08(3)	3.34(3)	3.59(3)	4.01(3)	4.29(3)	4.50(3)	4.66(3)
.90	2.79(3)	3.14(3)	3.41(3)	3.67(3)	4.10(3)	4.39(3)	4.62(3)	4.78(3)
.95	2.83(3)	3.19(3)	3.47(3)	3.74(3)	4.19(3)	4.49(3)	4.72(3)	4.89(3)
1.00	2.87(3)	3.24(3)	3.53(3)	3.81(3)	4.27(3)	4.58(3)	4.82(3)	5.00(3)
1.10	2.93(3)	3.33(3)	3.63(3)	3.92(3)	4.41(3)	4.74(3)	4.99(3)	5.18(3)
1.20	2.99(3)	3.40(3)	3.71(3)	4.02(3)	4.53(3)	4.88(3)	5.15(3)	5.35(3)
1.30	3.03(3)	3.46(3)	3.79(3)	4.11(3)	4.64(3)	5.00(3)	5.29(3)	5.49(3)
1.40	3.07(3)	3.51(3)	3.85(3)	4.18(3)	4.74(3)	5.12(3)	5.41(3)	5.63(3)
1.50	3.10(3)	3.56(3)	3.91(3)	4.25(3)	4.82(3)	5.22(3)	5.52(3)	5.74(3)
1.60	3.13(3)	3.60(3)	3.96(3)	4.31(3)	4.90(3)	5.30(3)	5.62(3)	5.85(3)
1.70	3.15(3)	3.63(3)	4.00(3)	4.36(3)	4.97(3)	5.39(3)	5.71(3)	5.95(3)
1.80	3.17(3)	3.66(3)	4.04(3)	4.41(3)	5.03(3)	5.46(3)	5.79(3)	6.04(3)
1.90	3.18(3)	3.68(3)	4.07(3)	4.45(3)	5.08(3)	5.52(3)	5.87(3)	6.12(3)
2.00	3.20(3)	3.70(3)	4.10(3)	4.48(3)	5.13(3)	5.58(3)	5.93(3)	6.19(3)

* The number in parentheses is the power of ten by which the preceeding entry is to be multiplied.



Graphical Data G-3.10. Stopping power of heavy ions in atomic krypton.

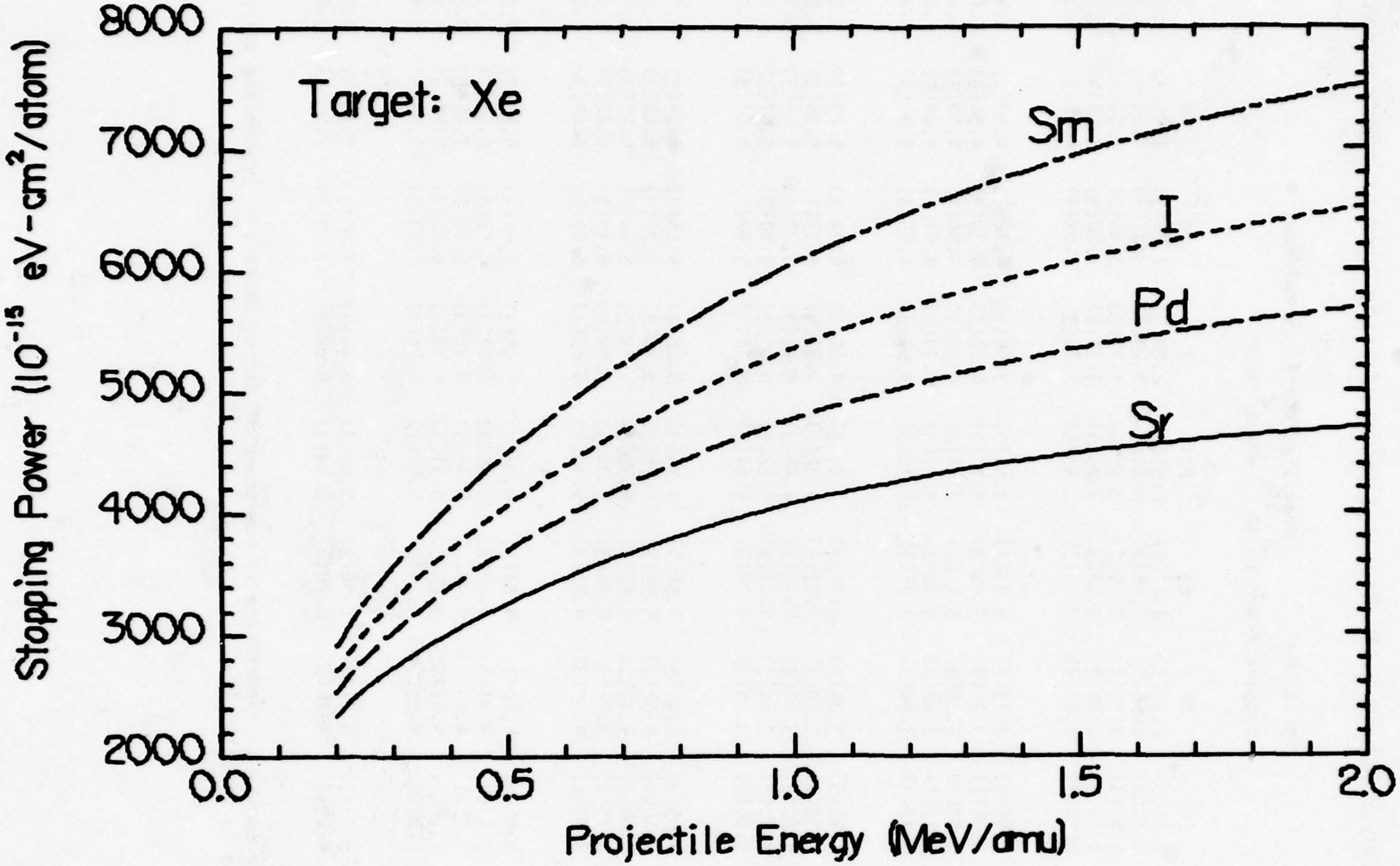
Tabular Data G-3.11. Stopping power of heavy ions in atomic xenon.

Units are: Heavy Ion Energy in MeV/amu,

Stopping Power in 10^{-15} eV-cm^2/atom

E	As *	Sr	Mo	Pd	I	Ce	Sm	Tb
.20	2.15(3)	2.31(3)	2.42(3)	2.53(3)	2.70(3)	2.81(3)	2.90(3)	2.96(3)
.25	2.36(3)	2.54(3)	2.68(3)	2.81(3)	3.03(3)	3.17(3)	3.28(3)	3.35(3)
.30	2.51(3)	2.72(3)	2.89(3)	3.04(3)	3.29(3)	3.45(3)	3.58(3)	3.67(3)
.35	2.63(3)	2.88(3)	3.06(3)	3.23(3)	3.51(3)	3.70(3)	3.84(3)	3.94(3)
.40	2.74(3)	3.01(3)	3.21(3)	3.40(3)	3.71(3)	3.92(3)	4.08(3)	4.19(3)
.45	2.84(3)	3.13(3)	3.35(3)	3.56(3)	3.90(3)	4.12(3)	4.30(3)	4.42(3)
.50	2.94(3)	3.25(3)	3.48(3)	3.70(3)	4.07(3)	4.32(3)	4.50(3)	4.64(3)
.55	3.03(3)	3.36(3)	3.61(3)	3.84(3)	4.23(3)	4.50(3)	4.70(3)	4.85(3)
.60	3.11(3)	3.46(3)	3.72(3)	3.97(3)	4.39(3)	4.67(3)	4.88(3)	5.04(3)
.65	3.19(3)	3.56(3)	3.83(3)	4.10(3)	4.54(3)	4.83(3)	5.06(3)	5.23(3)
.70	3.26(3)	3.64(3)	3.94(3)	4.21(3)	4.67(3)	4.99(3)	5.23(3)	5.40(3)
.75	3.33(3)	3.73(3)	4.03(3)	4.32(3)	4.81(3)	5.13(3)	5.38(3)	5.57(3)
.80	3.39(3)	3.81(3)	4.12(3)	4.43(3)	4.93(3)	5.27(3)	5.53(3)	5.72(3)
.85	3.45(3)	3.88(3)	4.21(3)	4.52(3)	5.05(3)	5.40(3)	5.67(3)	5.87(3)
.90	3.50(3)	3.95(3)	4.29(3)	4.61(3)	5.16(3)	5.52(3)	5.81(3)	6.02(3)
.95	3.55(3)	4.01(3)	4.36(3)	4.70(3)	5.26(3)	5.64(3)	5.94(3)	6.15(3)
1.00	3.60(3)	4.07(3)	4.43(3)	4.78(3)	5.36(3)	5.75(3)	6.06(3)	6.28(3)
1.10	3.68(3)	4.17(3)	4.55(3)	4.92(3)	5.53(3)	5.94(3)	6.27(3)	6.50(3)
1.20	3.75(3)	4.26(3)	4.66(3)	5.04(3)	5.69(3)	6.12(3)	6.46(3)	6.71(3)
1.30	3.81(3)	4.35(3)	4.76(3)	5.16(3)	5.83(3)	6.29(3)	6.64(3)	6.90(3)
1.40	3.86(3)	4.42(3)	4.84(3)	5.26(3)	5.96(3)	6.43(3)	6.80(3)	7.07(3)
1.50	3.91(3)	4.48(3)	4.92(3)	5.35(3)	6.07(3)	6.57(3)	6.95(3)	7.23(3)
1.60	3.95(3)	4.54(3)	4.99(3)	5.43(3)	6.18(3)	6.69(3)	7.09(3)	7.38(3)
1.70	3.98(3)	4.59(3)	5.05(3)	5.51(3)	6.28(3)	6.80(3)	7.21(3)	7.51(3)
1.80	4.01(3)	4.63(3)	5.11(3)	5.58(3)	6.36(3)	6.91(3)	7.33(3)	7.64(3)
1.90	4.03(3)	4.67(3)	5.16(3)	5.64(3)	6.44(3)	7.00(3)	7.43(3)	7.75(3)
2.00	4.06(3)	4.70(3)	5.20(3)	5.69(3)	6.52(3)	7.09(3)	7.53(3)	7.86(3)

* The number in parentheses is the power of ten by which the preceeding entry is to be multiplied.



Graphical Data G-3.12. Stopping power of heavy ions in atomic xenon.

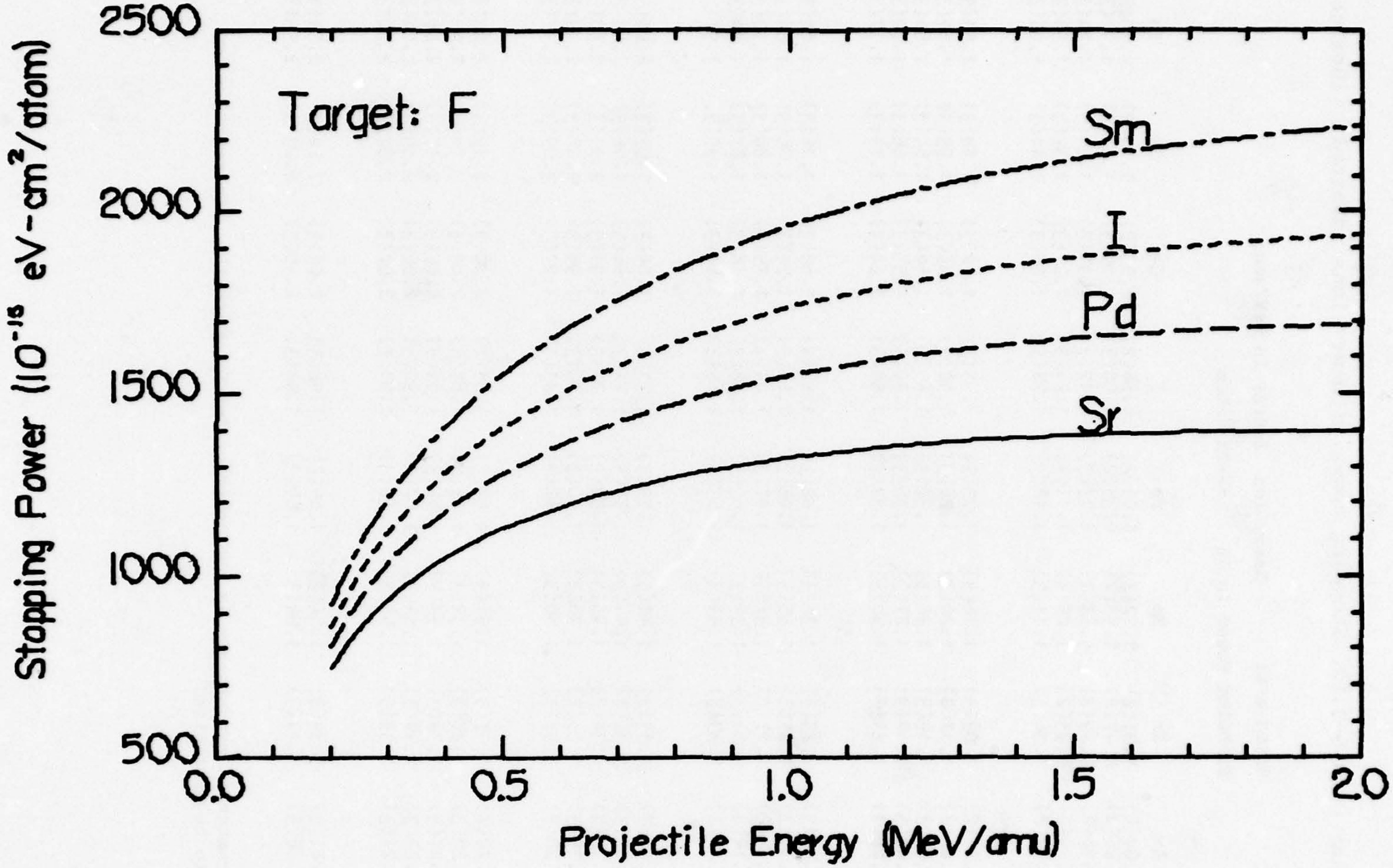
Tabular Data G-3.13. Stopping power of heavy ions in atomic fluorine.

Units are: Heavy Ion Energy in MeV/amu,

Stopping Power in 10^{-15} eV-cm^2/atom

E	As*	Sr	Mo	Pd	I	Ce	Sm	Tb
.20	6.89(2)	7.37(2)	7.72(2)	8.05(2)	8.58(2)	8.93(2)	9.19(2)	9.38(2)
.25	7.85(2)	8.47(2)	8.93(2)	9.35(2)	1.00(3)	1.05(3)	1.08(3)	1.11(3)
.30	8.56(2)	9.29(2)	9.84(2)	1.03(3)	1.12(3)	1.17(3)	1.21(3)	1.24(3)
.35	9.09(2)	9.93(2)	1.05(3)	1.11(3)	1.21(3)	1.27(3)	1.32(3)	1.36(3)
.40	9.52(2)	1.04(3)	1.11(3)	1.18(3)	1.28(3)	1.35(3)	1.41(3)	1.45(3)
.45	9.87(2)	1.09(3)	1.16(3)	1.23(3)	1.35(3)	1.42(3)	1.48(3)	1.53(3)
.50	1.02(3)	1.12(3)	1.20(3)	1.28(3)	1.40(3)	1.49(3)	1.55(3)	1.60(3)
.55	1.04(3)	1.15(3)	1.24(3)	1.32(3)	1.45(3)	1.54(3)	1.61(3)	1.66(3)
.60	1.06(3)	1.18(3)	1.27(3)	1.36(3)	1.50(3)	1.59(3)	1.66(3)	1.72(3)
.65	1.08(3)	1.21(3)	1.30(3)	1.39(3)	1.54(3)	1.64(3)	1.71(3)	1.77(3)
.70	1.10(3)	1.23(3)	1.33(3)	1.42(3)	1.57(3)	1.68(3)	1.76(3)	1.82(3)
.75	1.11(3)	1.25(3)	1.35(3)	1.45(3)	1.61(3)	1.71(3)	1.80(3)	1.86(3)
.80	1.13(3)	1.27(3)	1.37(3)	1.47(3)	1.64(3)	1.75(3)	1.84(3)	1.90(3)
.85	1.14(3)	1.28(3)	1.39(3)	1.49(3)	1.66(3)	1.78(3)	1.87(3)	1.94(3)
.90	1.15(3)	1.30(3)	1.41(3)	1.51(3)	1.69(3)	1.81(3)	1.90(3)	1.97(3)
.95	1.16(3)	1.31(3)	1.42(3)	1.53(3)	1.71(3)	1.84(3)	1.93(3)	2.00(3)
1.00	1.17(3)	1.32(3)	1.44(3)	1.55(3)	1.74(3)	1.86(3)	1.96(3)	2.03(3)
1.10	1.18(3)	1.34(3)	1.46(3)	1.58(3)	1.77(3)	1.91(3)	2.01(3)	2.08(3)
1.20	1.19(3)	1.35(3)	1.48(3)	1.60(3)	1.80(3)	1.94(3)	2.05(3)	2.13(3)
1.30	1.20(3)	1.37(3)	1.50(3)	1.62(3)	1.83(3)	1.97(3)	2.09(3)	2.17(3)
1.40	1.20(3)	1.37(3)	1.51(3)	1.64(3)	1.85(3)	2.00(3)	2.12(3)	2.20(3)
1.50	1.20(3)	1.38(3)	1.52(3)	1.65(3)	1.87(3)	2.03(3)	2.14(3)	2.23(3)
1.60	1.21(3)	1.39(3)	1.53(3)	1.66(3)	1.89(3)	2.05(3)	2.17(3)	2.26(3)
1.70	1.21(3)	1.39(3)	1.53(3)	1.67(3)	1.90(3)	2.06(3)	2.19(3)	2.28(3)
1.80	1.21(3)	1.39(3)	1.54(3)	1.68(3)	1.91(3)	2.08(3)	2.20(3)	2.30(3)
1.90	1.21(3)	1.39(3)	1.54(3)	1.68(3)	1.92(3)	2.09(3)	2.22(3)	2.31(3)
2.00	1.20(3)	1.39(3)	1.54(3)	1.69(3)	1.93(3)	2.10(3)	2.23(3)	2.33(3)

* The number in parentheses is the power of ten by which the preceeding entry is to be multiplied.



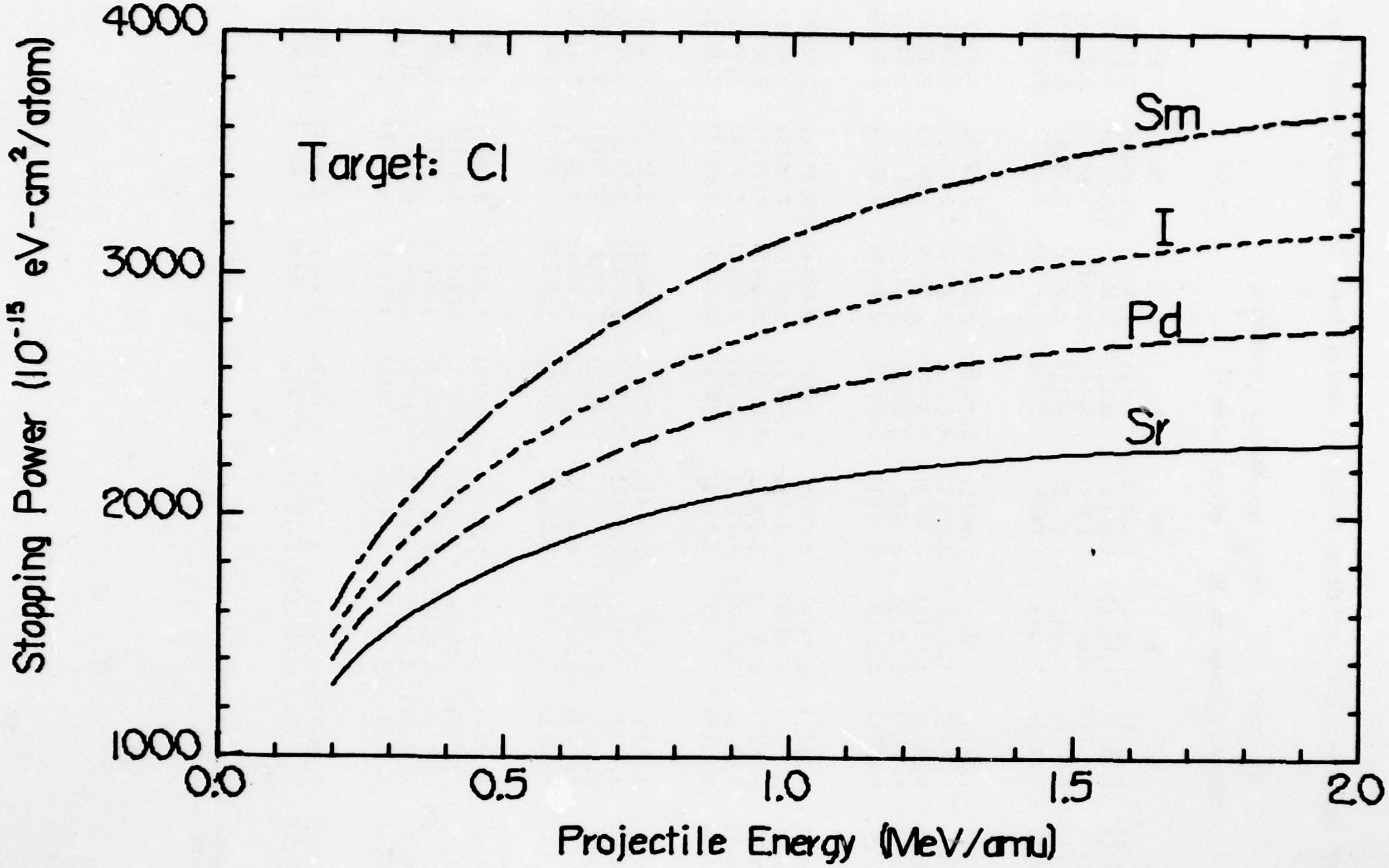
Graphical Data G-3.14. Stopping power of heavy ions in atomic fluorine.

Tabular Data G-3.15. Stopping power of heavy ions in atomic chlorine.

Units are: Heavy Ion Energy in MeV/amu,
Stopping Power in 10^{-15} eV-cm^2/atom

E	As	Sr	Mo	Pd	I	Ce	Sm	Tb
.20	1.20(3)*	1.29(3)	1.35(3)	1.40(3)	1.50(3)	1.56(3)	1.60(3)	1.64(3)
.25	1.31(3)	1.42(3)	1.49(3)	1.56(3)	1.68(3)	1.76(3)	1.81(3)	1.86(3)
.30	1.39(3)	1.52(3)	1.60(3)	1.69(3)	1.82(3)	1.91(3)	1.98(3)	2.03(3)
.35	1.46(3)	1.60(3)	1.70(3)	1.79(3)	1.95(3)	2.05(3)	2.13(3)	2.18(3)
.40	1.52(3)	1.67(3)	1.78(3)	1.88(3)	2.05(3)	2.17(3)	2.25(3)	2.32(3)
.45	1.57(3)	1.73(3)	1.85(3)	1.96(3)	2.15(3)	2.27(3)	2.37(3)	2.44(3)
.50	1.62(3)	1.79(3)	1.91(3)	2.04(3)	2.23(3)	2.37(3)	2.47(3)	2.54(3)
.55	1.66(3)	1.84(3)	1.97(3)	2.10(3)	2.31(3)	2.46(3)	2.57(3)	2.65(3)
.60	1.69(3)	1.88(3)	2.03(3)	2.16(3)	2.39(3)	2.54(3)	2.65(3)	2.74(3)
.65	1.73(3)	1.92(3)	2.07(3)	2.22(3)	2.45(3)	2.61(3)	2.73(3)	2.82(3)
.70	1.76(3)	1.96(3)	2.12(3)	2.27(3)	2.51(3)	2.68(3)	2.81(3)	2.90(3)
.75	1.78(3)	2.00(3)	2.16(3)	2.31(3)	2.57(3)	2.75(3)	2.88(3)	2.98(3)
.80	1.81(3)	2.03(3)	2.20(3)	2.36(3)	2.62(3)	2.80(3)	2.94(3)	3.05(3)
.85	1.83(3)	2.06(3)	2.23(3)	2.40(3)	2.67(3)	2.86(3)	3.00(3)	3.11(3)
.90	1.85(3)	2.08(3)	2.26(3)	2.43(3)	2.72(3)	2.91(3)	3.06(3)	3.17(3)
.95	1.86(3)	2.11(3)	2.29(3)	2.46(3)	2.76(3)	2.96(3)	3.11(3)	3.22(3)
1.00	1.88(3)	2.13(3)	2.31(3)	2.50(3)	2.80(3)	3.00(3)	3.16(3)	3.28(3)
1.10	1.91(3)	2.16(3)	2.36(3)	2.55(3)	2.86(3)	3.08(3)	3.25(3)	3.37(3)
1.20	1.93(3)	2.19(3)	2.40(3)	2.59(3)	2.92(3)	3.15(3)	3.32(3)	3.45(3)
1.30	1.94(3)	2.22(3)	2.43(3)	2.63(3)	2.97(3)	3.21(3)	3.39(3)	3.52(3)
1.40	1.96(3)	2.24(3)	2.46(3)	2.67(3)	3.02(3)	3.26(3)	3.45(3)	3.58(3)
1.50	1.97(3)	2.26(3)	2.48(3)	2.69(3)	3.06(3)	3.31(3)	3.50(3)	3.64(3)
1.60	1.97(3)	2.27(3)	2.50(3)	2.72(3)	3.09(3)	3.34(3)	3.54(3)	3.69(3)
1.70	1.98(3)	2.28(3)	2.51(3)	2.74(3)	3.12(3)	3.38(3)	3.58(3)	3.73(3)
1.80	1.98(3)	2.29(3)	2.52(3)	2.75(3)	3.14(3)	3.41(3)	3.62(3)	3.77(3)
1.90	1.98(3)	2.29(3)	2.53(3)	2.77(3)	3.16(3)	3.44(3)	3.65(3)	3.80(3)
2.00	1.98(3)	2.30(3)	2.54(3)	2.78(3)	3.18(3)	3.46(3)	3.68(3)	3.84(3)

* The number in parentheses is the power of ten by which the preceeding entry is to be multiplied.



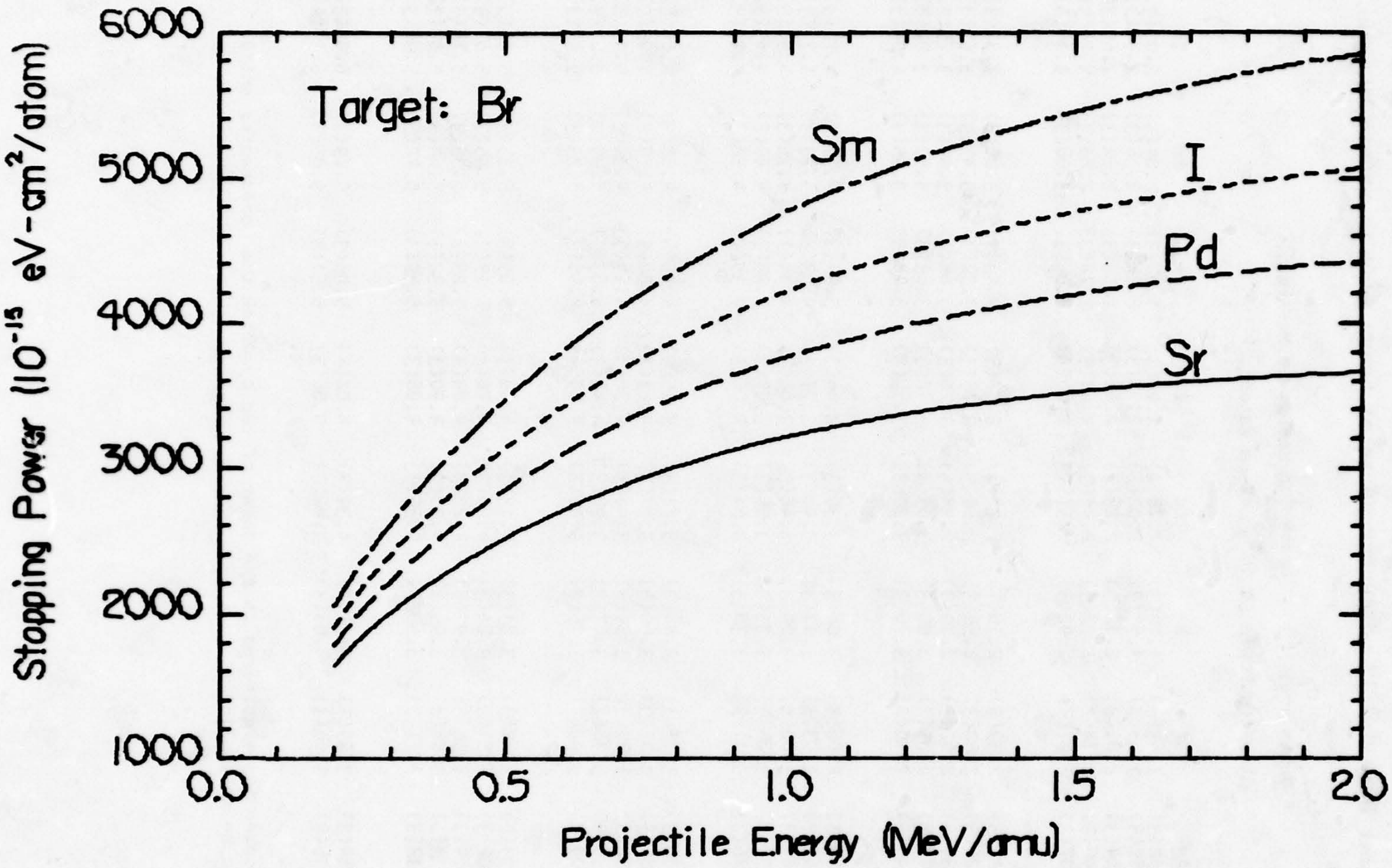
Graphical Data G-3.16. Stopping power of heavy ions in atomic chlorine.

Tabular Data G-3.17. Stopping power of heavy ions in atomic bromine.

Units are: Heavy Ion Energy in MeV/amu,
Stopping Power in 10^{-15} eV-cm^2/atom

E	As*	Sr	Mo	Pd	I	Ce	Sm	Tb
.20	1.52(3)	1.63(3)	1.70(3)	1.78(3)	1.90(3)	1.98(3)	2.04(3)	2.09(3)
.25	1.69(3)	1.83(3)	1.93(3)	2.02(3)	2.18(3)	2.28(3)	2.36(3)	2.41(3)
.30	1.84(3)	2.00(3)	2.12(3)	2.23(3)	2.41(3)	2.53(3)	2.62(3)	2.69(3)
.35	1.96(3)	2.14(3)	2.28(3)	2.41(3)	2.61(3)	2.75(3)	2.86(3)	2.94(3)
.40	2.07(3)	2.27(3)	2.42(3)	2.57(3)	2.80(3)	2.96(3)	3.08(3)	3.16(3)
.45	2.17(3)	2.39(3)	2.56(3)	2.72(3)	2.97(3)	3.15(3)	3.28(3)	3.37(3)
.50	2.26(3)	2.50(3)	2.68(3)	2.85(3)	3.13(3)	3.32(3)	3.47(3)	3.57(3)
.55	2.35(3)	2.60(3)	2.79(3)	2.98(3)	3.28(3)	3.48(3)	3.64(3)	3.75(3)
.60	2.42(3)	2.69(3)	2.90(3)	3.09(3)	3.42(3)	3.63(3)	3.80(3)	3.92(3)
.65	2.49(3)	2.78(3)	3.00(3)	3.20(3)	3.54(3)	3.78(3)	3.95(3)	4.08(3)
.70	2.56(3)	2.86(3)	3.08(3)	3.30(3)	3.66(3)	3.91(3)	4.09(3)	4.23(3)
.75	2.61(3)	2.93(3)	3.17(3)	3.40(3)	3.77(3)	4.03(3)	4.23(3)	4.37(3)
.80	2.67(3)	3.00(3)	3.24(3)	3.48(3)	3.88(3)	4.14(3)	4.35(3)	4.50(3)
.85	2.72(3)	3.06(3)	3.31(3)	3.56(3)	3.97(3)	4.25(3)	4.47(3)	4.63(3)
.90	2.76(3)	3.11(3)	3.38(3)	3.64(3)	4.06(3)	4.35(3)	4.58(3)	4.74(3)
.95	2.80(3)	3.17(3)	3.44(3)	3.71(3)	4.15(3)	4.45(3)	4.68(3)	4.85(3)
1.00	2.84(3)	3.21(3)	3.50(3)	3.77(3)	4.23(3)	4.54(3)	4.78(3)	4.95(3)
1.10	2.90(3)	3.29(3)	3.59(3)	3.88(3)	4.36(3)	4.69(3)	4.94(3)	5.13(3)
1.20	2.95(3)	3.36(3)	3.67(3)	3.98(3)	4.48(3)	4.83(3)	5.09(3)	5.29(3)
1.30	3.00(3)	3.42(3)	3.75(3)	4.06(3)	4.59(3)	4.95(3)	5.23(3)	5.43(3)
1.40	3.03(3)	3.47(3)	3.81(3)	4.13(3)	4.68(3)	5.05(3)	5.35(3)	5.56(3)
1.50	3.06(3)	3.51(3)	3.86(3)	4.20(3)	4.76(3)	5.15(3)	5.45(3)	5.67(3)
1.60	3.09(3)	3.55(3)	3.91(3)	4.25(3)	4.84(3)	5.24(3)	5.55(3)	5.78(3)
1.70	3.11(3)	3.58(3)	3.95(3)	4.30(3)	4.90(3)	5.32(3)	5.64(3)	5.87(3)
1.80	3.13(3)	3.61(3)	3.99(3)	4.35(3)	4.96(3)	5.39(3)	5.72(3)	5.96(3)
1.90	3.14(3)	3.63(3)	4.02(3)	4.39(3)	5.02(3)	5.45(3)	5.79(3)	6.03(3)
2.00	3.15(3)	3.65(3)	4.04(3)	4.42(3)	5.06(3)	5.51(3)	5.85(3)	6.11(3)

* The number in parentheses is the power of ten by which the preceeding entry is to be multiplied.



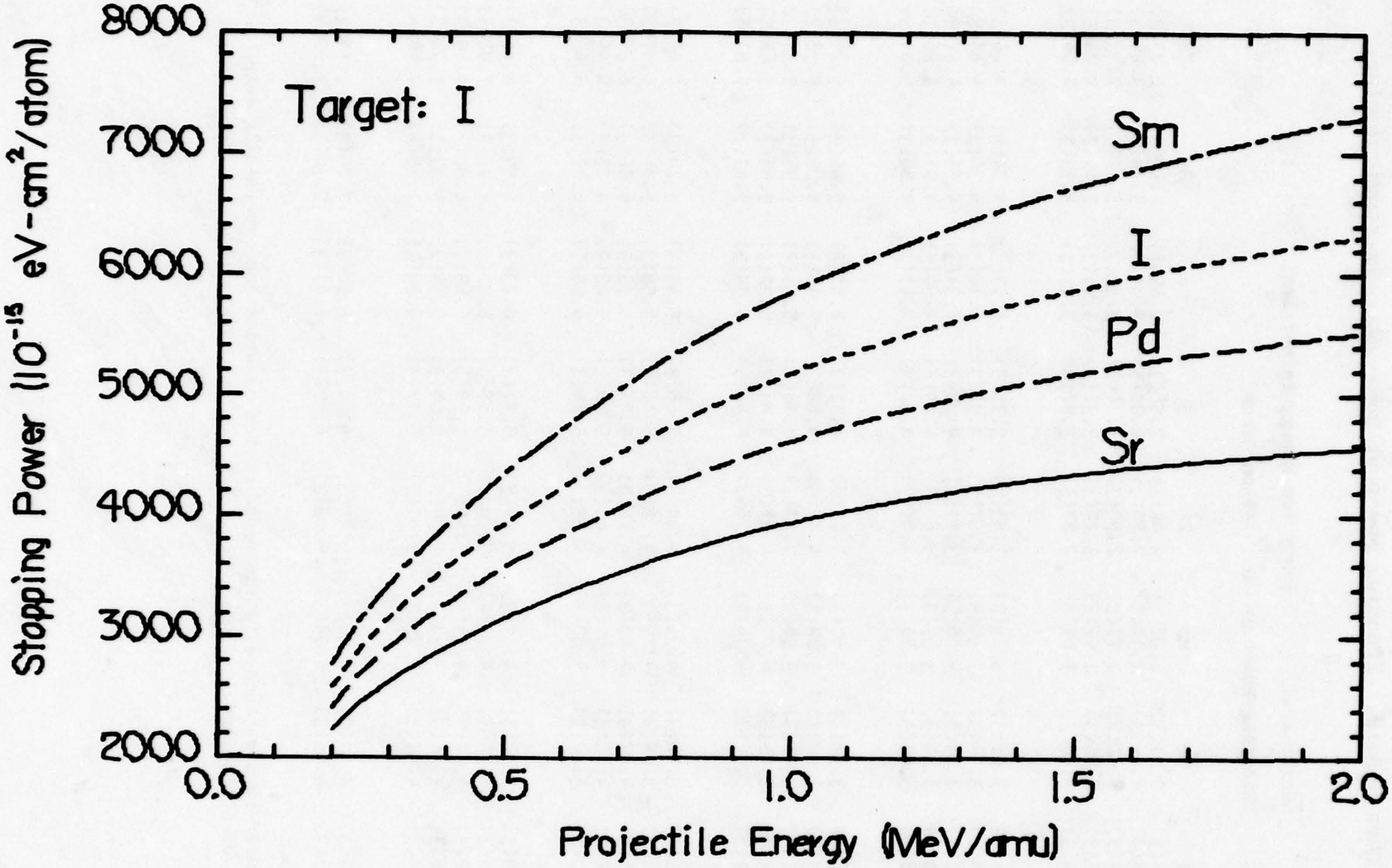
Graphical Data G-3.18. Stopping power of heavy ions in atomic bromine.

Tabular Data G-3.19. Stopping power of heavy ions in atomic iodine.

Units are: Heavy Ion Energy in MeV/amu,
Stopping Power in 10^{-15} eV-cm^2/atom

E	As*	Sr	Mo	Pd	I	Ce	Sm	Tb
.20	2.06(3)	2.21(3)	2.31(3)	2.41(3)	2.58(3)	2.69(3)	2.77(3)	2.83(3)
.25	2.26(3)	2.44(3)	2.57(3)	2.70(3)	2.90(3)	3.04(3)	3.14(3)	3.22(3)
.30	2.41(3)	2.62(3)	2.77(3)	2.92(3)	3.16(3)	3.32(3)	3.44(3)	3.53(3)
.35	2.53(3)	2.76(3)	2.94(3)	3.10(3)	3.37(3)	3.55(3)	3.69(3)	3.79(3)
.40	2.64(3)	2.90(3)	3.09(3)	3.27(3)	3.57(3)	3.77(3)	3.92(3)	4.04(3)
.45	2.74(3)	3.02(3)	3.23(3)	3.43(3)	3.75(3)	3.97(3)	4.14(3)	4.26(3)
.50	2.83(3)	3.13(3)	3.36(3)	3.57(3)	3.92(3)	4.16(3)	4.34(3)	4.47(3)
.55	2.92(3)	3.24(3)	3.48(3)	3.71(3)	4.08(3)	4.34(3)	4.53(3)	4.67(3)
.60	3.00(3)	3.34(3)	3.59(3)	3.83(3)	4.23(3)	4.50(3)	4.71(3)	4.86(3)
.65	3.08(3)	3.43(3)	3.70(3)	3.95(3)	4.38(3)	4.66(3)	4.88(3)	5.04(3)
.70	3.15(3)	3.52(3)	3.80(3)	4.07(3)	4.51(3)	4.81(3)	5.05(3)	5.21(3)
.75	3.21(3)	3.60(3)	3.89(3)	4.17(3)	4.64(3)	4.96(3)	5.20(3)	5.38(3)
.80	3.27(3)	3.68(3)	3.98(3)	4.27(3)	4.76(3)	5.09(3)	5.34(3)	5.53(3)
.85	3.33(3)	3.75(3)	4.07(3)	4.37(3)	4.88(3)	5.22(3)	5.48(3)	5.68(3)
.90	3.38(3)	3.82(3)	4.14(3)	4.46(3)	4.98(3)	5.34(3)	5.61(3)	5.81(3)
.95	3.43(3)	3.88(3)	4.22(3)	4.54(3)	5.08(3)	5.45(3)	5.74(3)	5.95(3)
1.00	3.48(3)	3.94(3)	4.29(3)	4.62(3)	5.18(3)	5.56(3)	5.85(3)	6.07(3)
1.10	3.56(3)	4.03(3)	4.40(3)	4.75(3)	5.35(3)	5.75(3)	6.06(3)	6.29(3)
1.20	3.62(3)	4.12(3)	4.51(3)	4.88(3)	5.50(3)	5.92(3)	6.25(3)	6.49(3)
1.30	3.68(3)	4.20(3)	4.60(3)	4.99(3)	5.64(3)	6.08(3)	6.43(3)	6.68(3)
1.40	3.74(3)	4.28(3)	4.69(3)	5.09(3)	5.77(3)	6.23(3)	6.59(3)	6.85(3)
1.50	3.78(3)	4.34(3)	4.77(3)	5.18(3)	5.88(3)	6.36(3)	6.73(3)	7.00(3)
1.60	3.82(3)	4.39(3)	4.83(3)	5.26(3)	5.98(3)	6.48(3)	6.87(3)	7.15(3)
1.70	3.86(3)	4.44(3)	4.90(3)	5.34(3)	6.08(3)	6.59(3)	6.99(3)	7.28(3)
1.80	3.88(3)	4.49(3)	4.95(3)	5.40(3)	6.17(3)	6.69(3)	7.10(3)	7.40(3)
1.90	3.91(3)	4.52(3)	5.00(3)	5.46(3)	6.24(3)	6.78(3)	7.20(3)	7.51(3)
2.00	3.93(3)	4.56(3)	5.04(3)	5.52(3)	6.32(3)	6.87(3)	7.30(3)	7.62(3)

* The number in parentheses is the power of ten by which the preceeding entry is to be multiplied.



Graphical Data G-3.20. Stopping power of heavy ions in atomic iodine.

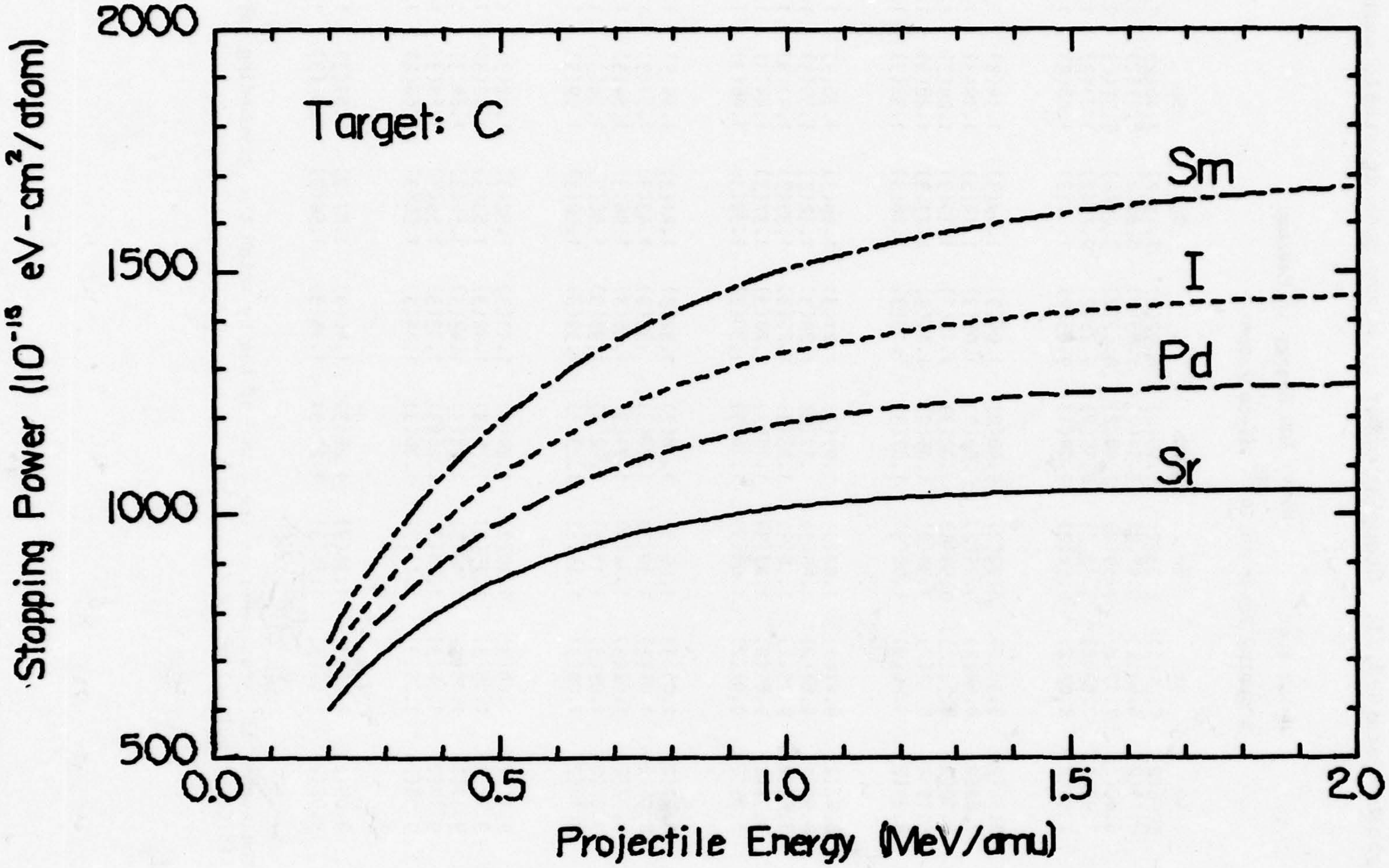
Tabular Data G-3.21. Stopping power of heavy ions in atomic carbon.

Units are: Heavy Ion Energy in MeV/amu,

Stopping Power in 10^{-15} eV-cm^2/atom

E	As	Sr	Mo	Pd	I	Ce	Sm	Tb
.20	5.56(2)*	5.95(2)	6.23(2)	6.49(2)	6.92(2)	7.19(2)	7.40(2)	7.55(2)
.25	6.14(2)	6.63(2)	6.98(2)	7.31(2)	7.85(2)	8.20(2)	8.47(2)	8.66(2)
.30	6.60(2)	7.17(2)	7.59(2)	7.98(2)	8.62(2)	9.04(2)	9.37(2)	9.60(2)
.35	6.99(2)	7.63(2)	8.10(2)	8.55(2)	9.28(2)	9.77(2)	1.01(3)	1.04(3)
.40	7.31(2)	8.02(2)	8.54(2)	9.04(2)	9.85(2)	1.04(3)	1.08(3)	1.11(3)
.45	7.58(2)	8.35(2)	8.92(2)	9.46(2)	1.04(3)	1.09(3)	1.14(3)	1.17(3)
.50	7.82(2)	8.64(2)	9.25(2)	9.84(2)	1.08(3)	1.14(3)	1.19(3)	1.23(3)
.55	8.02(2)	8.89(2)	9.54(2)	1.02(3)	1.12(3)	1.19(3)	1.24(3)	1.28(3)
.60	8.19(2)	9.11(2)	9.80(2)	1.05(3)	1.15(3)	1.23(3)	1.28(3)	1.32(3)
.65	8.34(2)	9.30(2)	1.00(3)	1.07(3)	1.18(3)	1.26(3)	1.32(3)	1.36(3)
.70	8.47(2)	9.47(2)	1.02(3)	1.09(3)	1.21(3)	1.29(3)	1.36(3)	1.40(3)
.75	8.59(2)	9.62(2)	1.04(3)	1.11(3)	1.24(3)	1.32(3)	1.39(3)	1.43(3)
.80	8.69(2)	9.75(2)	1.06(3)	1.13(3)	1.26(3)	1.35(3)	1.41(3)	1.46(3)
.85	8.77(2)	9.87(2)	1.07(3)	1.15(3)	1.28(3)	1.37(3)	1.44(3)	1.49(3)
.90	8.85(2)	9.97(2)	1.08(3)	1.16(3)	1.30(3)	1.39(3)	1.46(3)	1.52(3)
.95	8.91(2)	1.01(3)	1.09(3)	1.18(3)	1.32(3)	1.41(3)	1.49(3)	1.54(3)
1.00	8.96(2)	1.01(3)	1.10(3)	1.19(3)	1.33(3)	1.43(3)	1.51(3)	1.56(3)
1.10	9.02(2)	1.02(3)	1.12(3)	1.21(3)	1.36(3)	1.46(3)	1.54(3)	1.59(3)
1.20	9.07(2)	1.03(3)	1.13(3)	1.22(3)	1.38(3)	1.48(3)	1.56(3)	1.62(3)
1.30	9.10(2)	1.04(3)	1.14(3)	1.23(3)	1.39(3)	1.50(3)	1.59(3)	1.65(3)
1.40	9.11(2)	1.04(3)	1.14(3)	1.24(3)	1.41(3)	1.52(3)	1.60(3)	1.67(3)
1.50	9.12(2)	1.05(3)	1.15(3)	1.25(3)	1.42(3)	1.53(3)	1.62(3)	1.69(3)
1.60	9.11(2)	1.05(3)	1.15(3)	1.25(3)	1.43(3)	1.54(3)	1.64(3)	1.70(3)
1.70	9.10(2)	1.05(3)	1.16(3)	1.26(3)	1.43(3)	1.55(3)	1.65(3)	1.72(3)
1.80	9.08(2)	1.05(3)	1.16(3)	1.26(3)	1.44(3)	1.56(3)	1.66(3)	1.73(3)
1.90	9.05(2)	1.05(3)	1.16(3)	1.26(3)	1.45(3)	1.57(3)	1.67(3)	1.74(3)
2.00	9.02(2)	1.05(3)	1.16(3)	1.27(3)	1.45(3)	1.58(3)	1.67(3)	1.75(3)

* The number in parentheses is the power of ten by which the preceeding entry is to be multiplied.



Graphical Data G-3.22. Stopping power of heavy ions in atomic carbon.

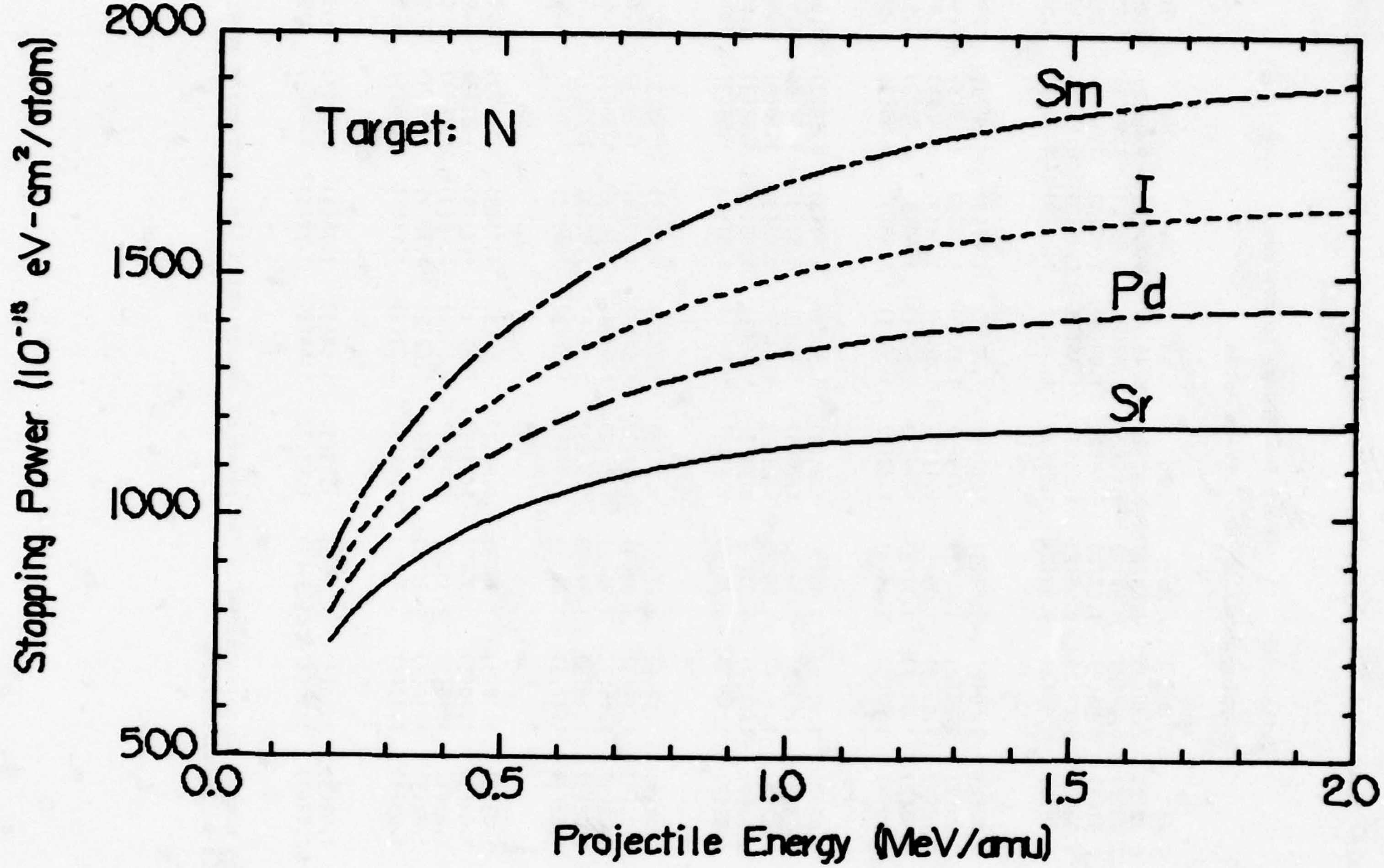
Tabular Data G-3.23. Stopping power of heavy ions in atomic nitrogen.

Units are: Heavy Ion Energy in MeV/amu,

Stopping Power in 10^{-15} eV-cm^2/atom

E	As *	Sr	Mo	Pd	I	Ce	Sm	Tb
.20	6.82(2)	7.30(2)	7.64(2)	7.97(2)	8.48(2)	8.82(2)	9.08(2)	9.26(2)
.25	7.45(2)	8.04(2)	8.47(2)	8.87(2)	9.52(2)	9.95(2)	1.03(3)	1.05(3)
.30	7.91(2)	8.58(2)	9.08(2)	9.55(2)	1.03(3)	1.08(3)	1.12(3)	1.15(3)
.35	8.26(2)	9.02(2)	9.58(2)	1.01(3)	1.10(3)	1.15(3)	1.20(3)	1.23(3)
.40	8.55(2)	9.38(2)	9.99(2)	1.06(3)	1.15(3)	1.22(3)	1.26(3)	1.30(3)
.45	8.80(2)	9.69(2)	1.04(3)	1.10(3)	1.20(3)	1.27(3)	1.32(3)	1.36(3)
.50	9.01(2)	9.96(2)	1.07(3)	1.13(3)	1.24(3)	1.32(3)	1.38(3)	1.42(3)
.55	9.20(2)	1.02(3)	1.09(3)	1.17(3)	1.28(3)	1.36(3)	1.42(3)	1.47(3)
.60	9.36(2)	1.04(3)	1.12(3)	1.19(3)	1.32(3)	1.40(3)	1.46(3)	1.51(3)
.65	9.50(2)	1.06(3)	1.14(3)	1.22(3)	1.35(3)	1.44(3)	1.50(3)	1.55(3)
.70	9.62(2)	1.07(3)	1.16(3)	1.24(3)	1.38(3)	1.47(3)	1.54(3)	1.59(3)
.75	9.73(2)	1.09(3)	1.18(3)	1.26(3)	1.40(3)	1.50(3)	1.57(3)	1.62(3)
.80	9.82(2)	1.10(3)	1.19(3)	1.28(3)	1.43(3)	1.52(3)	1.60(3)	1.65(3)
.85	9.90(2)	1.11(3)	1.21(3)	1.30(3)	1.45(3)	1.55(3)	1.63(3)	1.68(3)
.90	9.97(2)	1.12(3)	1.22(3)	1.31(3)	1.47(3)	1.57(3)	1.65(3)	1.71(3)
.95	1.00(3)	1.13(3)	1.23(3)	1.33(3)	1.48(3)	1.59(3)	1.67(3)	1.73(3)
1.00	1.01(3)	1.14(3)	1.24(3)	1.34(3)	1.50(3)	1.61(3)	1.69(3)	1.76(3)
1.10	1.02(3)	1.15(3)	1.26(3)	1.36(3)	1.53(3)	1.64(3)	1.73(3)	1.80(3)
1.20	1.02(3)	1.16(3)	1.27(3)	1.38(3)	1.55(3)	1.67(3)	1.76(3)	1.83(3)
1.30	1.03(3)	1.17(3)	1.28(3)	1.39(3)	1.57(3)	1.69(3)	1.79(3)	1.86(3)
1.40	1.03(3)	1.18(3)	1.29(3)	1.40(3)	1.59(3)	1.71(3)	1.81(3)	1.89(3)
1.50	1.03(3)	1.18(3)	1.30(3)	1.41(3)	1.60(3)	1.73(3)	1.83(3)	1.91(3)
1.60	1.03(3)	1.18(3)	1.30(3)	1.42(3)	1.61(3)	1.75(3)	1.85(3)	1.93(3)
1.70	1.03(3)	1.19(3)	1.31(3)	1.42(3)	1.62(3)	1.76(3)	1.86(3)	1.94(3)
1.80	1.03(3)	1.19(3)	1.31(3)	1.43(3)	1.63(3)	1.77(3)	1.88(3)	1.96(3)
1.90	1.03(3)	1.19(3)	1.31(3)	1.43(3)	1.64(3)	1.78(3)	1.89(3)	1.97(3)
2.00	1.02(3)	1.18(3)	1.31(3)	1.43(3)	1.64(3)	1.79(3)	1.90(3)	1.98(3)

* The number in parentheses is the power of ten by which the preceeding entry is to be multiplied.



Graphical Data G-3.24. Stopping power of heavy ions in atomic nitrogen.

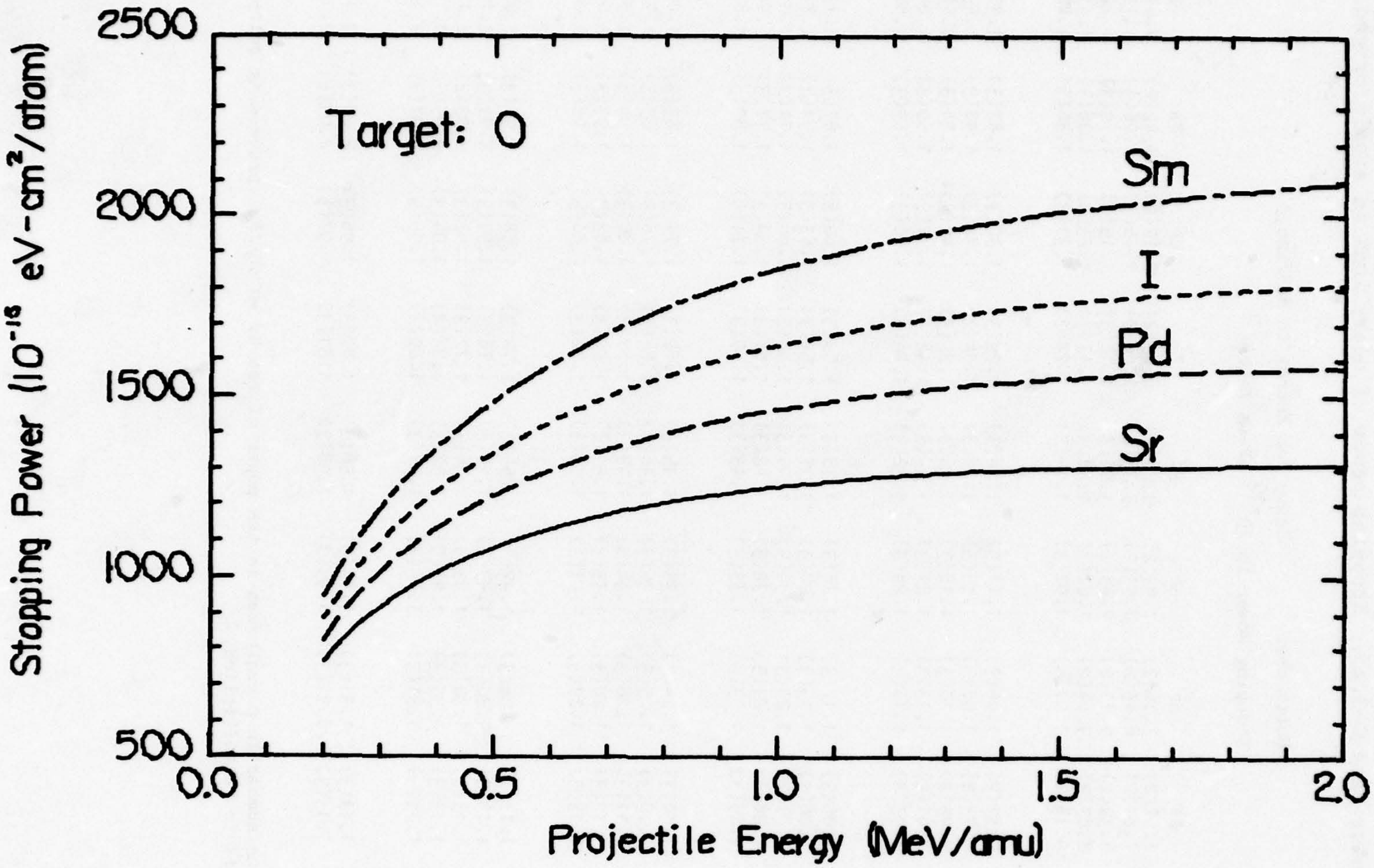
Tabular Data G-3.25. Stopping power of heavy ions in atomic oxygen.

Units are: Heavy Ion Energy in MeV/amu,

Stopping Power in 10^{-15} eV-cm^2/atom

E	As*	Sr	Mo	Pd	I	Ce	Sm	Tb
.20	7.07(2)	7.56(2)	7.92(2)	8.26(2)	8.80(2)	9.15(2)	9.42(2)	9.61(2)
.25	7.84(2)	8.45(2)	8.91(2)	9.33(2)	1.00(3)	1.05(3)	1.08(3)	1.11(3)
.30	8.39(2)	9.11(2)	9.65(2)	1.01(3)	1.10(3)	1.15(3)	1.19(3)	1.22(3)
.35	8.83(2)	9.64(2)	1.02(3)	1.08(3)	1.17(3)	1.23(3)	1.28(3)	1.31(3)
.40	9.18(2)	1.01(3)	1.07(3)	1.14(3)	1.24(3)	1.31(3)	1.36(3)	1.40(3)
.45	9.47(2)	1.04(3)	1.11(3)	1.18(3)	1.29(3)	1.37(3)	1.42(3)	1.47(3)
.50	9.73(2)	1.07(3)	1.15(3)	1.22(3)	1.34(3)	1.42(3)	1.48(3)	1.53(3)
.55	9.95(2)	1.10(3)	1.18(3)	1.26(3)	1.39(3)	1.47(3)	1.54(3)	1.59(3)
.60	1.01(3)	1.13(3)	1.21(3)	1.29(3)	1.43(3)	1.52(3)	1.59(3)	1.64(3)
.65	1.03(3)	1.15(3)	1.24(3)	1.32(3)	1.46(3)	1.56(3)	1.63(3)	1.68(3)
.70	1.05(3)	1.17(3)	1.26(3)	1.35(3)	1.50(3)	1.60(3)	1.67(3)	1.73(3)
.75	1.06(3)	1.19(3)	1.28(3)	1.37(3)	1.53(3)	1.63(3)	1.71(3)	1.77(3)
.80	1.07(3)	1.20(3)	1.30(3)	1.40(3)	1.55(3)	1.66(3)	1.74(3)	1.80(3)
.85	1.08(3)	1.21(3)	1.32(3)	1.42(3)	1.58(3)	1.69(3)	1.77(3)	1.84(3)
.90	1.09(3)	1.23(3)	1.33(3)	1.43(3)	1.60(3)	1.71(3)	1.80(3)	1.87(3)
.95	1.10(3)	1.24(3)	1.35(3)	1.45(3)	1.62(3)	1.74(3)	1.83(3)	1.90(3)
1.00	1.10(3)	1.25(3)	1.36(3)	1.46(3)	1.64(3)	1.76(3)	1.85(3)	1.92(3)
1.10	1.11(3)	1.26(3)	1.38(3)	1.49(3)	1.67(3)	1.80(3)	1.90(3)	1.97(3)
1.20	1.12(3)	1.28(3)	1.39(3)	1.51(3)	1.70(3)	1.83(3)	1.93(3)	2.01(3)
1.30	1.13(3)	1.29(3)	1.41(3)	1.53(3)	1.72(3)	1.86(3)	1.96(3)	2.04(3)
1.40	1.13(3)	1.29(3)	1.42(3)	1.54(3)	1.74(3)	1.88(3)	1.99(3)	2.07(3)
1.50	1.13(3)	1.30(3)	1.43(3)	1.55(3)	1.76(3)	1.90(3)	2.01(3)	2.10(3)
1.60	1.13(3)	1.30(3)	1.43(3)	1.56(3)	1.77(3)	1.92(3)	2.03(3)	2.12(3)
1.70	1.13(3)	1.31(3)	1.44(3)	1.57(3)	1.79(3)	1.94(3)	2.05(3)	2.14(3)
1.80	1.13(3)	1.31(3)	1.44(3)	1.57(3)	1.80(3)	1.95(3)	2.07(3)	2.15(3)
1.90	1.13(3)	1.31(3)	1.44(3)	1.58(3)	1.80(3)	1.96(3)	2.08(3)	2.17(3)
2.00	1.13(3)	1.31(3)	1.45(3)	1.58(3)	1.81(3)	1.97(3)	2.09(3)	2.18(3)

* The number in parentheses is the power of ten by which the preceeding entry is to be multiplied.



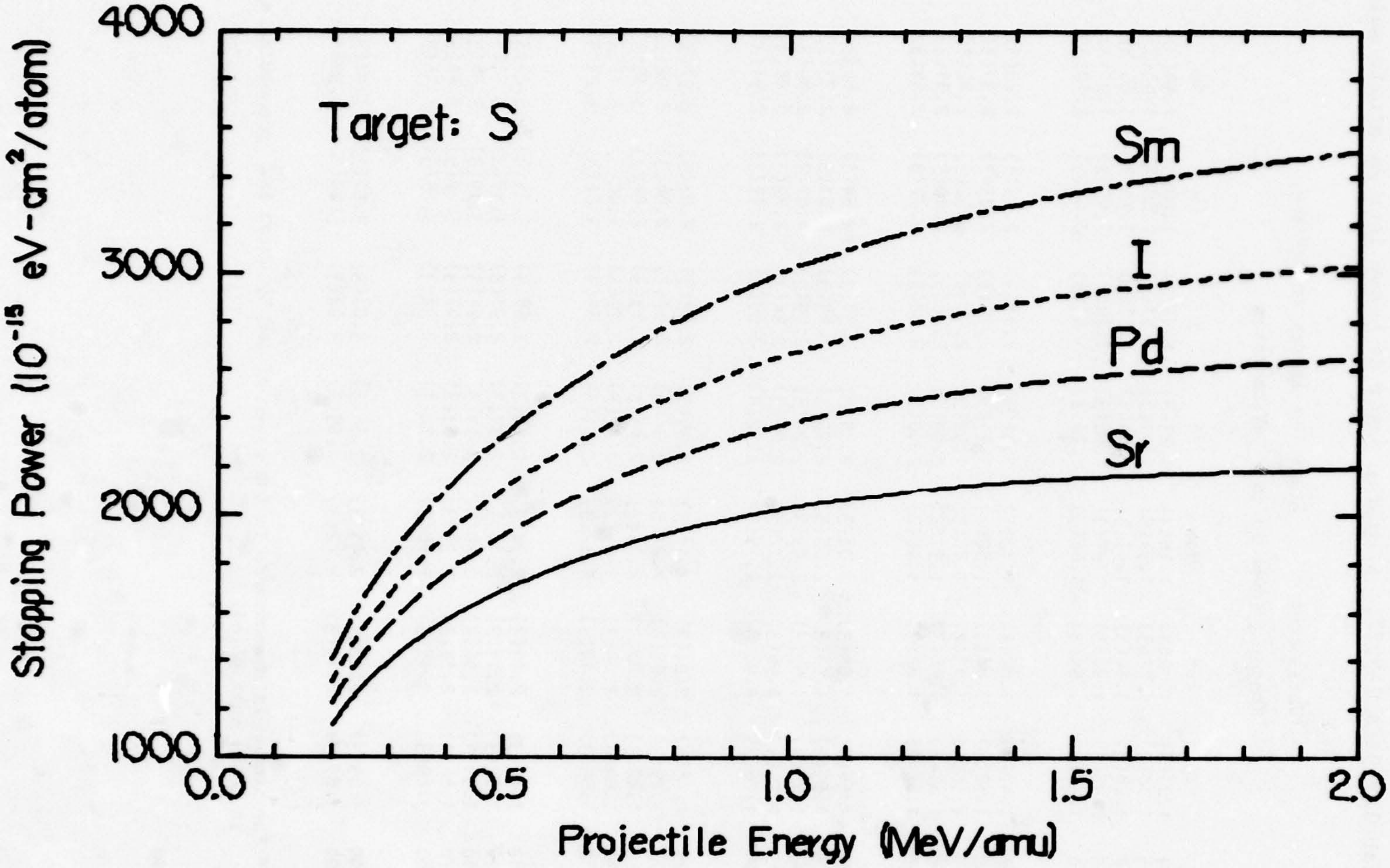
Graphical Data G-3.26. Stopping power of heavy ions in atomic oxygen.

Tabular Data G-3.27. Stopping power of heavy ions in atomic sulfur.

Units are: Heavy Ion Energy in MeV/amu,
Stopping Power in 10^{-15} eV-cm^2/atom

E	As	Sr	Mo	Pd	I	Ce	Sm	Tb
.20	1.05(3)*	1.12(3)	1.18(3)	1.23(3)	1.31(3)	1.36(3)	1.40(3)	1.43(3)
.25	1.18(3)	1.27(3)	1.34(3)	1.41(3)	1.51(3)	1.58(3)	1.63(3)	1.67(3)
.30	1.28(3)	1.39(3)	1.47(3)	1.55(3)	1.67(3)	1.75(3)	1.82(3)	1.86(3)
.35	1.35(3)	1.48(3)	1.57(3)	1.66(3)	1.80(3)	1.90(3)	1.97(3)	2.02(3)
.40	1.42(3)	1.56(3)	1.66(3)	1.76(3)	1.91(3)	2.02(3)	2.10(3)	2.16(3)
.45	1.47(3)	1.62(3)	1.73(3)	1.84(3)	2.01(3)	2.13(3)	2.22(3)	2.28(3)
.50	1.52(3)	1.68(3)	1.80(3)	1.91(3)	2.10(3)	2.23(3)	2.32(3)	2.39(3)
.55	1.56(3)	1.73(3)	1.86(3)	1.98(3)	2.18(3)	2.32(3)	2.42(3)	2.50(3)
.60	1.60(3)	1.78(3)	1.91(3)	2.04(3)	2.26(3)	2.40(3)	2.51(3)	2.59(3)
.65	1.63(3)	1.82(3)	1.96(3)	2.10(3)	2.32(3)	2.47(3)	2.59(3)	2.67(3)
.70	1.66(3)	1.86(3)	2.01(3)	2.15(3)	2.38(3)	2.54(3)	2.66(3)	2.75(3)
.75	1.69(3)	1.90(3)	2.05(3)	2.20(3)	2.44(3)	2.61(3)	2.73(3)	2.83(3)
.80	1.72(3)	1.93(3)	2.09(3)	2.24(3)	2.49(3)	2.67(3)	2.80(3)	2.90(3)
.85	1.74(3)	1.96(3)	2.12(3)	2.28(3)	2.54(3)	2.72(3)	2.86(3)	2.96(3)
.90	1.76(3)	1.98(3)	2.15(3)	2.32(3)	2.59(3)	2.77(3)	2.91(3)	3.02(3)
.95	1.78(3)	2.01(3)	2.18(3)	2.35(3)	2.63(3)	2.82(3)	2.97(3)	3.07(3)
1.00	1.79(3)	2.03(3)	2.21(3)	2.38(3)	2.67(3)	2.86(3)	3.02(3)	3.13(3)
1.10	1.82(3)	2.06(3)	2.25(3)	2.43(3)	2.73(3)	2.94(3)	3.10(3)	3.21(3)
1.20	1.84(3)	2.09(3)	2.29(3)	2.47(3)	2.79(3)	3.00(3)	3.17(3)	3.29(3)
1.30	1.85(3)	2.12(3)	2.32(3)	2.51(3)	2.84(3)	3.06(3)	3.23(3)	3.36(3)
1.40	1.87(3)	2.13(3)	2.34(3)	2.54(3)	2.88(3)	3.11(3)	3.29(3)	3.42(3)
1.50	1.87(3)	2.15(3)	2.36(3)	2.57(3)	2.91(3)	3.15(3)	3.33(3)	3.47(3)
1.60	1.88(3)	2.16(3)	2.38(3)	2.59(3)	2.94(3)	3.19(3)	3.38(3)	3.52(3)
1.70	1.88(3)	2.17(3)	2.39(3)	2.61(3)	2.97(3)	3.22(3)	3.41(3)	3.56(3)
1.80	1.89(3)	2.18(3)	2.40(3)	2.62(3)	2.99(3)	3.25(3)	3.45(3)	3.59(3)
1.90	1.89(3)	2.18(3)	2.41(3)	2.64(3)	3.01(3)	3.27(3)	3.48(3)	3.62(3)
2.00	1.89(3)	2.19(3)	2.42(3)	2.65(3)	3.03(3)	3.29(3)	3.50(3)	3.65(3)

* The number in parentheses is the power of ten by which the preceeding entry is to be multiplied.



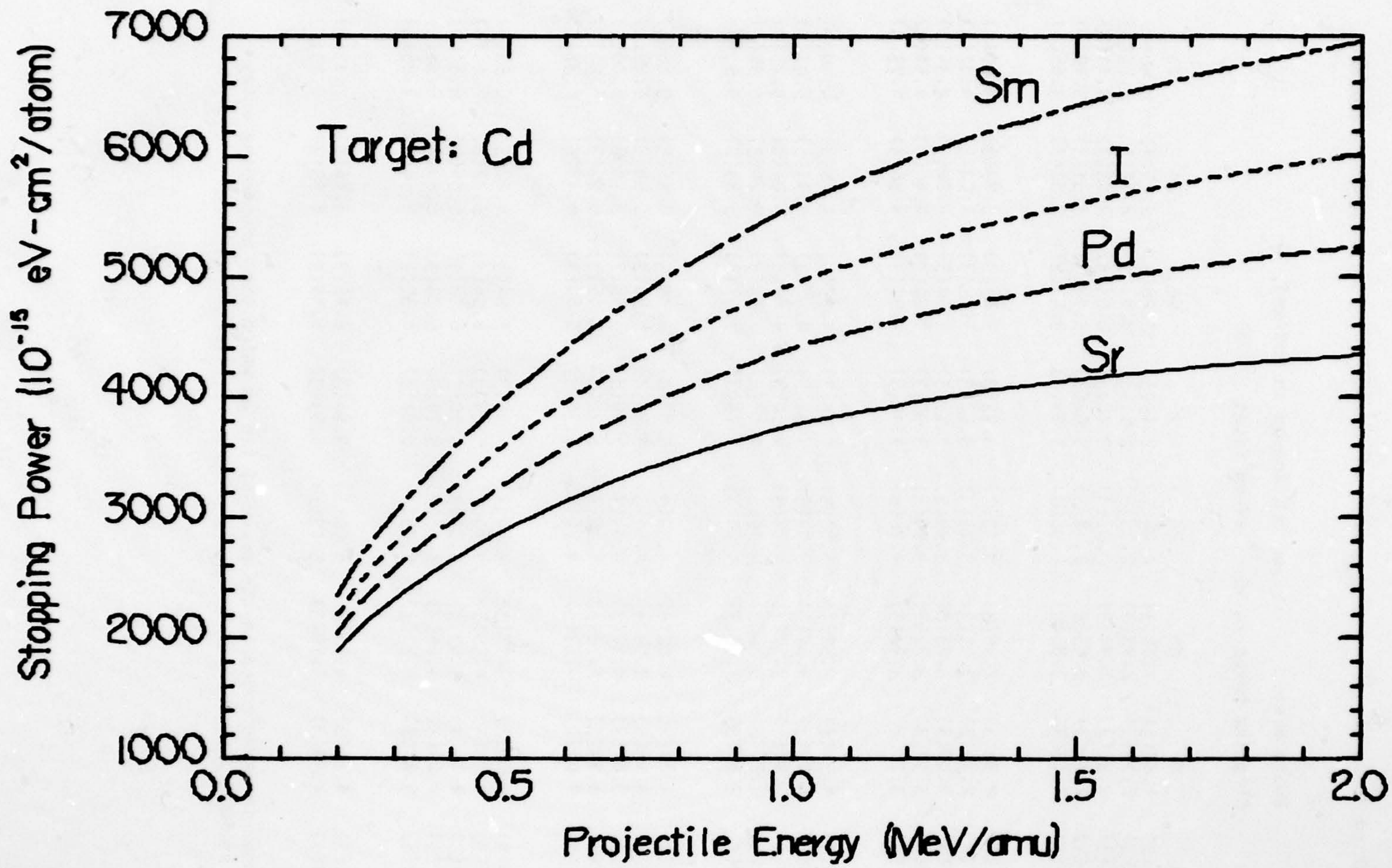
Graphical Data G-3.28. Stopping power of heavy ions in atomic sulfur.

Tabular Data G-3.29. Stopping power of heavy ions in atomic cadmium.

Units are: Heavy Ion Energy in MeV/amu,
Stopping Power in 10^{-15} eV-cm^2/atom

E	As*	Sr	Mo	Pd	I	Ce	Sm	Tb
.20	1.74(3)	1.87(3)	1.96(3)	2.04(3)	2.19(3)	2.28(3)	2.35(3)	2.40(3)
.25	1.95(3)	2.11(3)	2.23(3)	2.33(3)	2.51(3)	2.63(3)	2.72(3)	2.79(3)
.30	2.12(3)	2.31(3)	2.44(3)	2.57(3)	2.78(3)	2.93(3)	3.03(3)	3.11(3)
.35	2.26(3)	2.47(3)	2.63(3)	2.78(3)	3.02(3)	3.18(3)	3.31(3)	3.40(3)
.40	2.39(3)	2.62(3)	2.80(3)	2.96(3)	3.23(3)	3.42(3)	3.56(3)	3.66(3)
.45	2.51(3)	2.76(3)	2.95(3)	3.13(3)	3.43(3)	3.63(3)	3.79(3)	3.90(3)
.50	2.61(3)	2.89(3)	3.09(3)	3.29(3)	3.62(3)	3.83(3)	4.00(3)	4.12(3)
.55	2.71(3)	3.00(3)	3.23(3)	3.44(3)	3.79(3)	4.02(3)	4.20(3)	4.34(3)
.60	2.80(3)	3.11(3)	3.35(3)	3.58(3)	3.95(3)	4.20(3)	4.40(3)	4.54(3)
.65	2.88(3)	3.21(3)	3.47(3)	3.70(3)	4.10(3)	4.37(3)	4.58(3)	4.73(3)
.70	2.96(3)	3.31(3)	3.57(3)	3.83(3)	4.24(3)	4.53(3)	4.75(3)	4.90(3)
.75	3.03(3)	3.40(3)	3.67(3)	3.94(3)	4.38(3)	4.68(3)	4.91(3)	5.07(3)
.80	3.10(3)	3.48(3)	3.77(3)	4.04(3)	4.50(3)	4.82(3)	5.06(3)	5.23(3)
.85	3.16(3)	3.56(3)	3.86(3)	4.14(3)	4.62(3)	4.95(3)	5.20(3)	5.38(3)
.90	3.22(3)	3.63(3)	3.94(3)	4.24(3)	4.74(3)	5.07(3)	5.33(3)	5.53(3)
.95	3.27(3)	3.69(3)	4.02(3)	4.32(3)	4.84(3)	5.19(3)	5.46(3)	5.66(3)
1.00	3.32(3)	3.76(3)	4.09(3)	4.41(3)	4.94(3)	5.30(3)	5.58(3)	5.79(3)
1.10	3.39(3)	3.85(3)	4.20(3)	4.54(3)	5.10(3)	5.49(3)	5.78(3)	6.00(3)
1.20	3.46(3)	3.94(3)	4.30(3)	4.66(3)	5.25(3)	5.65(3)	5.97(3)	6.20(3)
1.30	3.52(3)	4.01(3)	4.39(3)	4.76(3)	5.38(3)	5.80(3)	6.13(3)	6.37(3)
1.40	3.56(3)	4.08(3)	4.47(3)	4.86(3)	5.50(3)	5.94(3)	6.28(3)	6.53(3)
1.50	3.61(3)	4.14(3)	4.55(3)	4.94(3)	5.61(3)	6.06(3)	6.42(3)	6.68(3)
1.60	3.64(3)	4.19(3)	4.61(3)	5.02(3)	5.70(3)	6.18(3)	6.54(3)	6.81(3)
1.70	3.67(3)	4.23(3)	4.66(3)	5.08(3)	5.79(3)	6.28(3)	6.66(3)	6.94(3)
1.80	3.70(3)	4.27(3)	4.71(3)	5.15(3)	5.87(3)	6.37(3)	6.76(3)	7.05(3)
1.90	3.72(3)	4.31(3)	4.76(3)	5.20(3)	5.94(3)	6.46(3)	6.86(3)	7.15(3)
2.00	3.74(3)	4.34(3)	4.80(3)	5.25(3)	6.01(3)	6.54(3)	6.95(3)	7.25(3)

* The number in parentheses is the power of ten by which the preceeding entry is to be multiplied.



Graphical Data G-3.30. Stopping power of heavy ions in atomic cadmium.

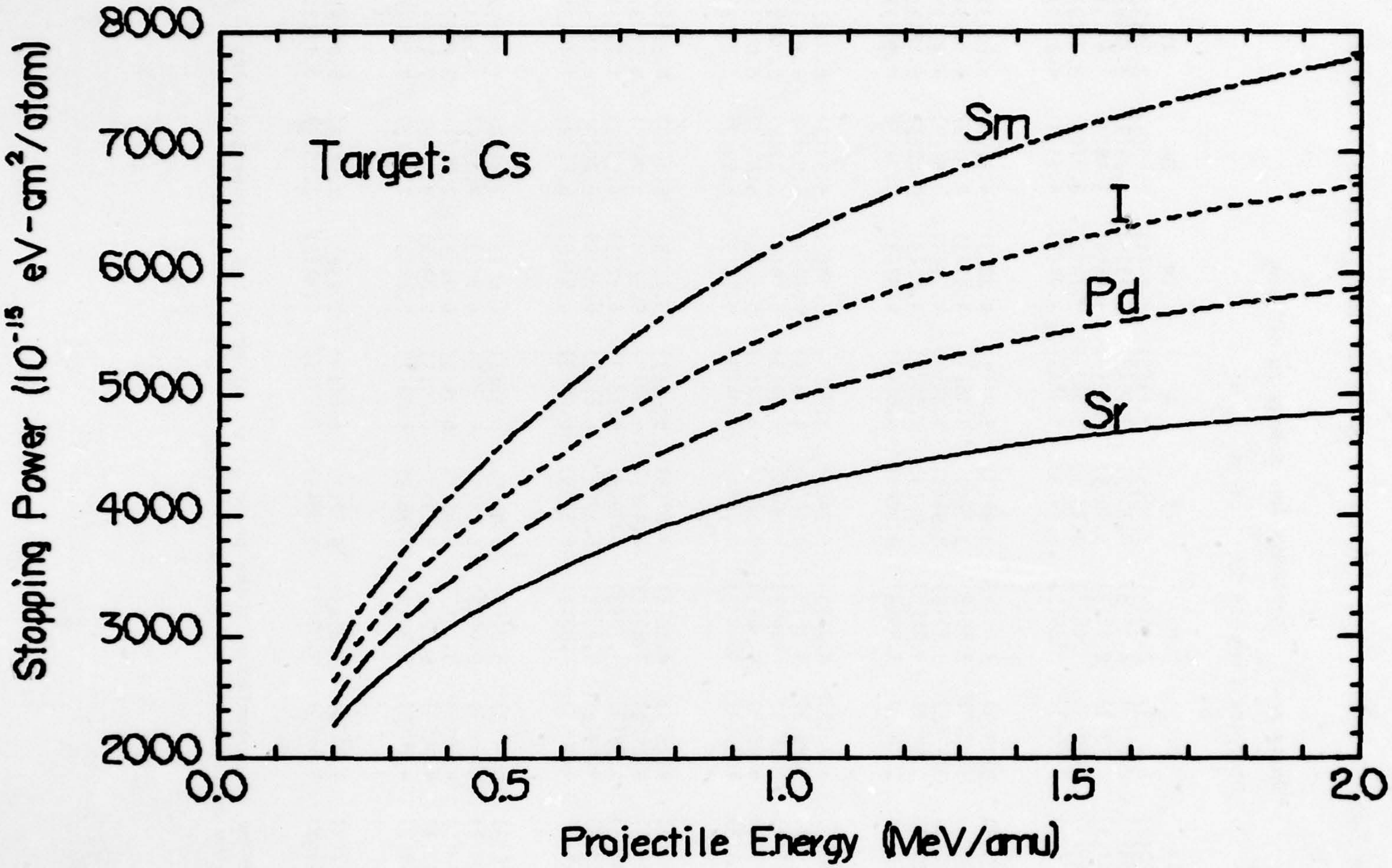
Tabular Data G-3.31. Stopping power of heavy ions in atomic cesium.

Units are: Heavy Ion Energy in MeV/amu,

Stopping Power in 10^{-15} eV-cm^2/atom

E	As*	Sr	Mo	Pd	I	Ce	Sm	Tb
.20	2.10(3)	2.25(3)	2.36(3)	2.46(3)	2.63(3)	2.74(3)	2.83(3)	2.89(3)
.25	2.33(3)	2.52(3)	2.65(3)	2.78(3)	2.99(3)	3.13(3)	3.24(3)	3.32(3)
.30	2.51(3)	2.72(3)	2.88(3)	3.04(3)	3.29(3)	3.45(3)	3.58(3)	3.67(3)
.35	2.65(3)	2.90(3)	3.08(3)	3.25(3)	3.54(3)	3.72(3)	3.87(3)	3.97(3)
.40	2.78(3)	3.05(3)	3.25(3)	3.44(3)	3.76(3)	3.97(3)	4.13(3)	4.25(3)
.45	2.90(3)	3.19(3)	3.41(3)	3.62(3)	3.97(3)	4.20(3)	4.37(3)	4.50(3)
.50	3.00(3)	3.32(3)	3.56(3)	3.79(3)	4.16(3)	4.41(3)	4.60(3)	4.74(3)
.55	3.10(3)	3.44(3)	3.70(3)	3.94(3)	4.34(3)	4.61(3)	4.81(3)	4.97(3)
.60	3.20(3)	3.55(3)	3.82(3)	4.08(3)	4.51(3)	4.80(3)	5.02(3)	5.18(3)
.65	3.28(3)	3.66(3)	3.94(3)	4.22(3)	4.67(3)	4.97(3)	5.21(3)	5.38(3)
.70	3.36(3)	3.76(3)	4.06(3)	4.34(3)	4.82(3)	5.14(3)	5.39(3)	5.57(3)
.75	3.44(3)	3.85(3)	4.16(3)	4.46(3)	4.96(3)	5.30(3)	5.56(3)	5.75(3)
.80	3.51(3)	3.94(3)	4.26(3)	4.58(3)	5.10(3)	5.45(3)	5.72(3)	5.92(3)
.85	3.57(3)	4.02(3)	4.36(3)	4.68(3)	5.22(3)	5.59(3)	5.87(3)	6.08(3)
.90	3.63(3)	4.09(3)	4.44(3)	4.78(3)	5.34(3)	5.72(3)	6.02(3)	6.23(3)
.95	3.69(3)	4.16(3)	4.52(3)	4.87(3)	5.46(3)	5.85(3)	6.16(3)	6.38(3)
1.00	3.74(3)	4.23(3)	4.60(3)	4.96(3)	5.56(3)	5.97(3)	6.29(3)	6.52(3)
1.10	3.81(3)	4.33(3)	4.72(3)	5.10(3)	5.73(3)	6.17(3)	6.50(3)	6.74(3)
1.20	3.88(3)	4.42(3)	4.83(3)	5.23(3)	5.89(3)	6.35(3)	6.70(3)	6.96(3)
1.30	3.94(3)	4.50(3)	4.93(3)	5.34(3)	6.04(3)	6.51(3)	6.88(3)	7.15(3)
1.40	4.00(3)	4.57(3)	5.02(3)	5.45(3)	6.17(3)	6.66(3)	7.04(3)	7.32(3)
1.50	4.04(3)	4.64(3)	5.09(3)	5.54(3)	6.28(3)	6.80(3)	7.19(3)	7.49(3)
1.60	4.08(3)	4.69(3)	5.16(3)	5.62(3)	6.39(3)	6.92(3)	7.33(3)	7.63(3)
1.70	4.11(3)	4.74(3)	5.22(3)	5.69(3)	6.49(3)	7.03(3)	7.46(3)	7.77(3)
1.80	4.14(3)	4.78(3)	5.28(3)	5.76(3)	6.58(3)	7.14(3)	7.57(3)	7.89(3)
1.90	4.17(3)	4.82(3)	5.33(3)	5.82(3)	6.66(3)	7.23(3)	7.68(3)	8.01(3)
2.00	4.19(3)	4.86(3)	5.37(3)	5.88(3)	6.73(3)	7.32(3)	7.78(3)	8.11(3)

* The number in parentheses is the power of ten by which the preceeding entry is to be multiplied.



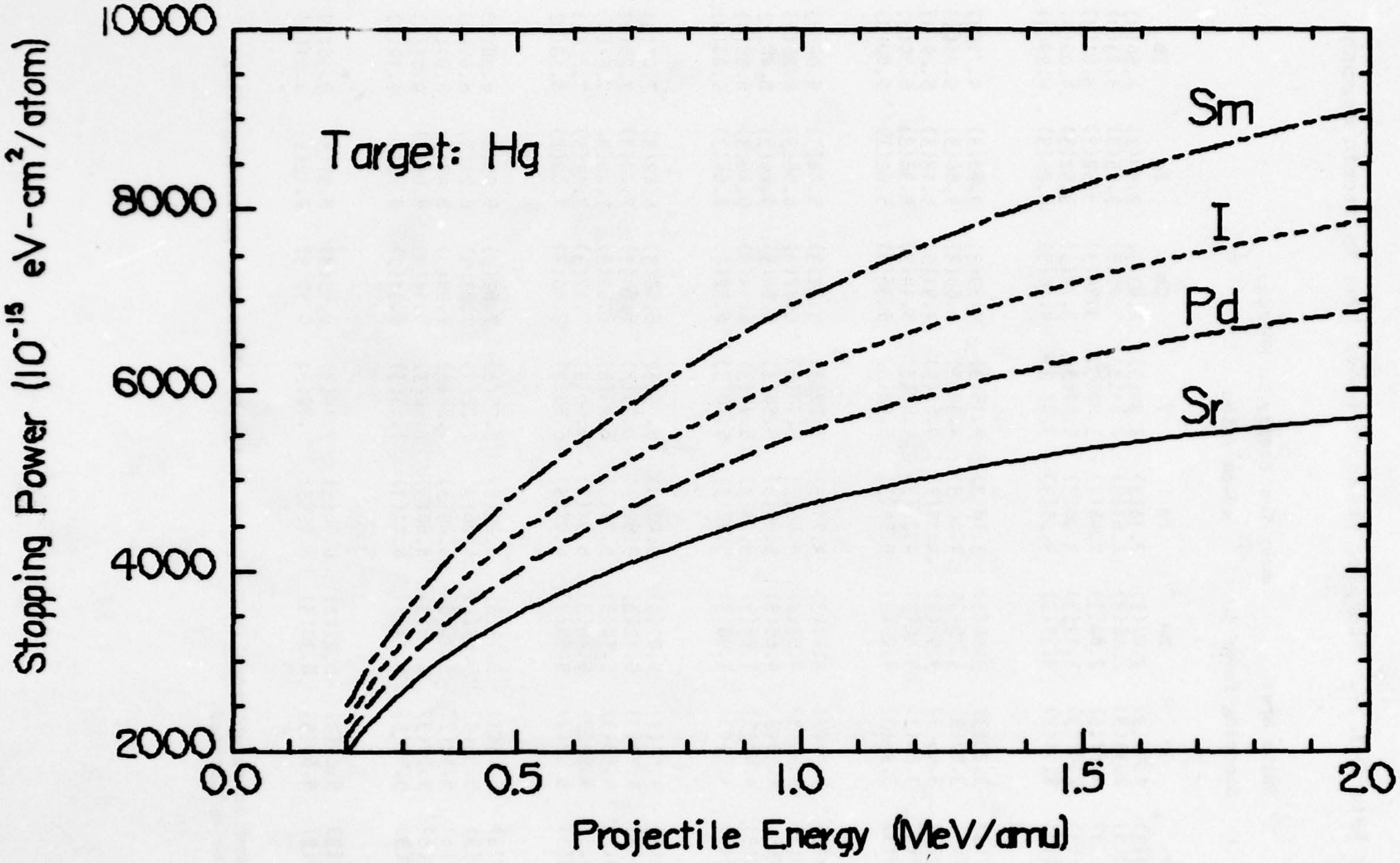
Graphical Data G-3. 32. Stopping power of heavy ions in atomic cesium.

Tabular Data G-3.33. Stopping power of heavy ions in atomic mercury.

Units are: Heavy Ion Energy in MeV/amu,
Stopping Power in 10^{-15} eV-cm^2/atom

E	As*	Sr	Mo	Pd	I	Ce	Sm	Tb
.20	1.83(3)	1.97(3)	2.07(3)	2.16(3)	2.32(3)	2.42(3)	2.50(3)	2.56(3)
.25	2.18(3)	2.35(3)	2.48(3)	2.61(3)	2.81(3)	2.95(3)	3.05(3)	3.13(3)
.30	2.45(3)	2.67(3)	2.82(3)	2.98(3)	3.22(3)	3.39(3)	3.52(3)	3.61(3)
.35	2.67(3)	2.92(3)	3.11(3)	3.28(3)	3.57(3)	3.77(3)	3.92(3)	4.02(3)
.40	2.86(3)	3.14(3)	3.35(3)	3.55(3)	3.88(3)	4.10(3)	4.26(3)	4.39(3)
.45	3.02(3)	3.33(3)	3.56(3)	3.78(3)	4.15(3)	4.39(3)	4.58(3)	4.71(3)
.50	3.17(3)	3.50(3)	3.76(3)	4.00(3)	4.39(3)	4.66(3)	4.86(3)	5.01(3)
.55	3.30(3)	3.66(3)	3.93(3)	4.19(3)	4.62(3)	4.91(3)	5.13(3)	5.29(3)
.60	3.42(3)	3.81(3)	4.10(3)	4.37(3)	4.83(3)	5.14(3)	5.38(3)	5.55(3)
.65	3.53(3)	3.94(3)	4.25(3)	4.54(3)	5.03(3)	5.36(3)	5.62(3)	5.80(3)
.70	3.64(3)	4.07(3)	4.40(3)	4.71(3)	5.22(3)	5.57(3)	5.84(3)	6.04(3)
.75	3.74(3)	4.19(3)	4.53(3)	4.86(3)	5.40(3)	5.77(3)	6.06(3)	6.26(3)
.80	3.83(3)	4.30(3)	4.66(3)	5.00(3)	5.58(3)	5.96(3)	6.26(3)	6.48(3)
.85	3.92(3)	4.41(3)	4.78(3)	5.14(3)	5.74(3)	6.14(3)	6.46(3)	6.68(3)
.90	4.00(3)	4.51(3)	4.90(3)	5.27(3)	5.90(3)	6.32(3)	6.64(3)	6.88(3)
.95	4.08(3)	4.61(3)	5.01(3)	5.40(3)	6.05(3)	6.48(3)	6.82(3)	7.07(3)
1.00	4.16(3)	4.70(3)	5.12(3)	5.52(3)	6.19(3)	6.64(3)	7.00(3)	7.25(3)
1.10	4.28(3)	4.85(3)	5.30(3)	5.72(3)	6.43(3)	6.92(3)	7.29(3)	7.57(3)
1.20	4.39(3)	4.99(3)	5.46(3)	5.91(3)	6.66(3)	7.17(3)	7.57(3)	7.86(3)
1.30	4.48(3)	5.12(3)	5.60(3)	6.07(3)	6.86(3)	7.40(3)	7.82(3)	8.13(3)
1.40	4.57(3)	5.23(3)	5.73(3)	6.23(3)	7.05(3)	7.62(3)	8.05(3)	8.38(3)
1.50	4.64(3)	5.33(3)	5.85(3)	6.36(3)	7.22(3)	7.81(3)	8.27(3)	8.60(3)
1.60	4.71(3)	5.42(3)	5.96(3)	6.49(3)	7.38(3)	7.99(3)	8.47(3)	8.81(3)
1.70	4.77(3)	5.50(3)	6.06(3)	6.60(3)	7.52(3)	8.16(3)	8.65(3)	9.01(3)
1.80	4.82(3)	5.57(3)	6.14(3)	6.71(3)	7.65(3)	8.31(3)	8.82(3)	9.19(3)
1.90	4.87(3)	5.63(3)	6.22(3)	6.80(3)	7.78(3)	8.45(3)	8.97(3)	9.36(3)
2.00	4.91(3)	5.69(3)	6.30(3)	6.89(3)	7.89(3)	8.58(3)	9.12(3)	9.51(3)

* The number in parentheses is the power of ten by which the preceeding entry is to be multiplied.



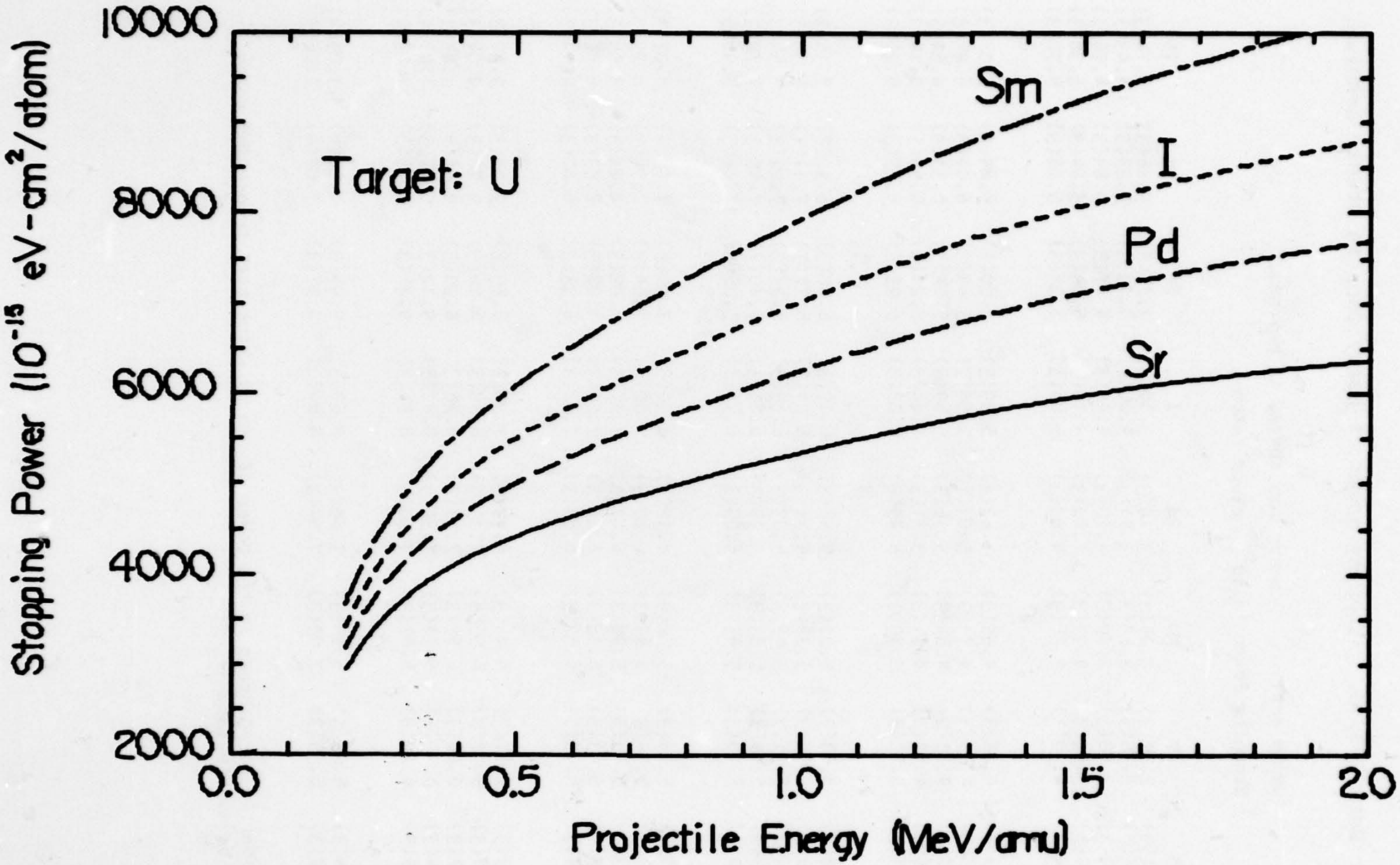
Graphical Data G-3.34. Stopping power of heavy ions in atomic mercury.

Tabular Data G-3.35. Stopping power of heavy ions in atomic uranium.

Units are: Heavy Ion **Energy in MeV/amu,**
Stopping Power in 10^{-15} eV-cm^2/atom

E	As	Sr	Mo	Pd	I	Ce	Sm	Tb
.20	2.71(3)*	2.91(3)	3.05(3)	3.18(3)	3.40(3)	3.55(3)	3.66(3)	3.74(3)
.25	3.11(3)	3.36(3)	3.54(3)	3.71(3)	4.00(3)	4.19(3)	4.33(3)	4.43(3)
.30	3.39(3)	3.68(3)	3.90(3)	4.10(3)	4.44(3)	4.67(3)	4.84(3)	4.96(3)
.35	3.59(3)	3.92(3)	4.17(3)	4.40(3)	4.78(3)	5.04(3)	5.24(3)	5.38(3)
.40	3.74(3)	4.10(3)	4.38(3)	4.63(3)	5.06(3)	5.34(3)	5.56(3)	5.72(3)
.45	3.86(3)	4.26(3)	4.55(3)	4.83(3)	5.29(3)	5.60(3)	5.84(3)	6.01(3)
.50	3.97(3)	4.39(3)	4.71(3)	5.01(3)	5.50(3)	5.83(3)	6.09(3)	6.27(3)
.55	4.07(3)	4.51(3)	4.84(3)	5.16(3)	5.69(3)	6.04(3)	6.31(3)	6.51(3)
.60	4.15(3)	4.62(3)	4.97(3)	5.31(3)	5.86(3)	6.24(3)	6.53(3)	6.74(3)
.65	4.24(3)	4.73(3)	5.10(3)	5.45(3)	6.03(3)	6.43(3)	6.73(3)	6.95(3)
.70	4.32(3)	4.83(3)	5.21(3)	5.58(3)	6.19(3)	6.60(3)	6.92(3)	7.15(3)
.75	4.39(3)	4.92(3)	5.32(3)	5.71(3)	6.34(3)	6.77(3)	7.11(3)	7.35(3)
.80	4.46(3)	5.01(3)	5.43(3)	5.83(3)	6.49(3)	6.94(3)	7.29(3)	7.54(3)
.85	4.53(3)	5.10(3)	5.53(3)	5.94(3)	6.63(3)	7.10(3)	7.46(3)	7.72(3)
.90	4.60(3)	5.18(3)	5.63(3)	6.05(3)	6.77(3)	7.25(3)	7.62(3)	7.90(3)
.95	4.66(3)	5.26(3)	5.72(3)	6.16(3)	6.90(3)	7.40(3)	7.78(3)	8.07(3)
1.00	4.72(3)	5.34(3)	5.81(3)	6.26(3)	7.02(3)	7.54(3)	7.94(3)	8.23(3)
1.10	4.83(3)	5.49(3)	5.99(3)	6.47(3)	7.27(3)	7.82(3)	8.24(3)	8.55(3)
1.20	4.94(3)	5.63(3)	6.15(3)	6.66(3)	7.50(3)	8.08(3)	8.53(3)	8.86(3)
1.30	5.04(3)	5.75(3)	6.30(3)	6.83(3)	7.72(3)	8.33(3)	8.80(3)	9.14(3)
1.40	5.13(3)	5.87(3)	6.44(3)	6.99(3)	7.92(3)	8.55(3)	9.04(3)	9.40(3)
1.50	5.21(3)	5.97(3)	6.56(3)	7.13(3)	8.10(3)	8.76(3)	9.27(3)	9.64(3)
1.60	5.27(3)	6.06(3)	6.67(3)	7.27(3)	8.26(3)	8.95(3)	9.48(3)	9.87(3)
1.70	5.34(3)	6.15(3)	6.78(3)	7.39(3)	8.41(3)	9.12(3)	9.67(3)	1.01(4)
1.80	5.39(3)	6.22(3)	6.87(3)	7.50(3)	8.56(3)	9.28(3)	9.85(3)	1.03(4)
1.90	5.44(3)	6.29(3)	6.95(3)	7.60(3)	8.69(3)	9.44(3)	1.00(4)	1.05(4)
2.00	5.48(3)	6.35(3)	7.03(3)	7.69(3)	8.80(3)	9.57(3)	1.02(4)	1.06(4)

* The number in parentheses is the power of ten by which the preceeding entry is to be multiplied.



Graphical Data G-3.36. Stopping power of heavy ions in atomic uranium.

G-4. ENERGY DEPOSITION IN GASES

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Introduction

Impact of energetic ions on high density gas targets leads to excitation and ionization both by direct projectile-target collisions as well as due to secondary particles (notably electrons liberated in target ionization events) colliding with the target. The details of this energy deposition, the rate at which specific states are produced, and the nature of the final states are the subject of this section. Published information is of four types:

1) Direct observations of the energy required to create an ion pair (a positive and a negative ion) in the target; this quantity, often given the symbol W, permits calculation of the net ionization produced by a particle as it comes to rest.

2) Theoretical computations of the division of deposited energy between different final states performed utilizing available cross section information.

3) Experimental measurements of the rate at which a particular excited state is formed when a specified projectile traverses a high pressure target.

4) Certain observations of the optical spectra induced by ion impact on high pressure targets with particular emphasis on the emission of continua that are related to the interaction of excited atoms with their neighbors.

Information of all four types is presented here but regrettably they do not present a comprehensive picture.

Tabular Data G-4.1. Energy to create an ion pair by H^+, He^{2+}, or electron impact on a pure gas.

Target Gas	Energy to Create an Ion Pair - eV/pair H^+	He^{2+}	e
He	45.2	46.0	42.3
Ne	39.3	36.55	36.4
Ar	26.6	26.4	26.3
Kr	23.0	24.00	24.05
Xe	20.5	21.7	21.9
H_2	36.6	36.4	36.30
CO		34.65	32.75
N_2		36.39	34.65
O_2		32.23	30.83
H_2O		37.76	
BF_3		35.63	
CO_2		34.26	32.80
N_2O		34.43	
CH_4		29.4	
C_2H_2		27.64	
C_2H_4		28.0	
$C\,C\ell_2F_2$		29.5	
SF_6		35.7	
Air		35.0	

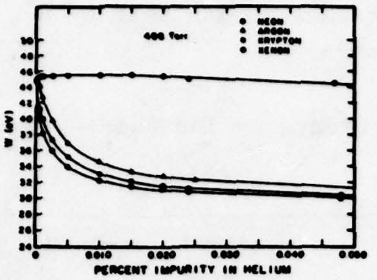
Note: These values are expected to be independent of projectile energy; they in fact represent experimental data taken with 3.6 MeV H^+, 5 MeV He^{2+}, and with electrons at unspecified high energy.

References: J. E. Parks et al., J. Chem. Phys. 57, 5467 (1972).

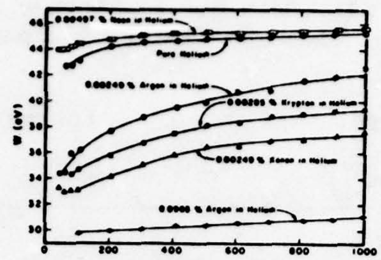
T. E. Bortner and G. S. Hurst, Phys. Rev. 93, 1236 (1954).

G. S. Hurst, T. E. Bortner, and R. E. Glick, J. Chem. Phys. 42, 713 (1965). This reference also contains data for more complex hydrocarbons.

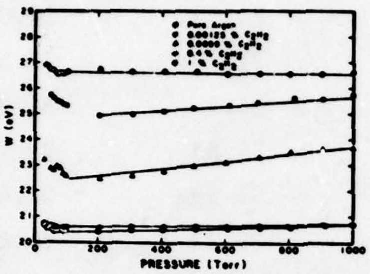
L. G. Christophorou, "Atomic and Molecular Radiation Physics" (Wiley Interscience New York, 1971).



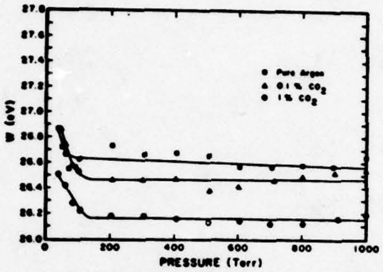
Plot of W values in mixtures of helium with other noble gases as a function of their concentration.



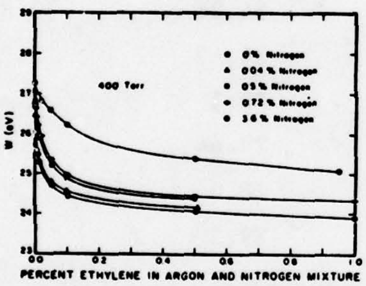
Plot of W values in mixtures of helium with specified concentrations of certain of the other noble gases as a function of the total pressure.



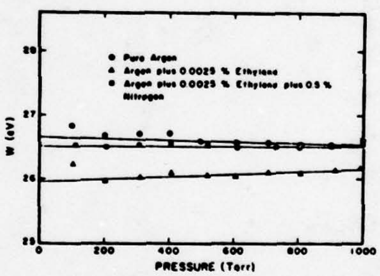
A plot of measured W values vs pressure for selected concentrations of C_2H_4 in Ar.



A plot of measured W values vs pressure for selected concentrations of CO_2 in Ar.



A plot of measured W values in a ternary mixture of argon, ethylene, and nitrogen. W is plotted against percent of ethylene at chosen nitrogen concentrations.



A plot of measured W values in a ternary mixture of argon, ethylene, and nitrogen. W is plotted against total pressure for pure argon, for a binary concentration, and for a ternary concentration.

Graphical Data G-4.2. Energy to create an ion pair by H^+ (3.6 MeV) ion impact on binary gas mixtures.

Note: The graphs show W values (eV/ion pair) for helium and argon mixed with various gases. Data are as a function of total pressure, or of concentration at a fixed total pressure.

Reference: J.E. Parks et al., J. Chem. Phys. 57, 5467 (1972).

Tabular Data G-4.3. Energy to create an ion pair by He^{2+} ion impact on binary gas mixtures.

To provide W values (eV/ion pair) for gas mixtures it is convenient to use an empirical formula. Let P_i be the pressure of gas 1 and P_j be the pressure of gas 2; also let W_i be the W value for gas 1, W_j the value for gas 2, and W_m the value for the mixture of 1 and 2 at pressures P_i and P_j. Then:

$$\frac{1}{W_m} = \left(\frac{1}{W_i} - \frac{1}{W_j}\right) Z_{ij} + \frac{1}{W_j}$$

where

$$Z_{ij} = \frac{P_i}{P_i + a_{ij} P_j}$$

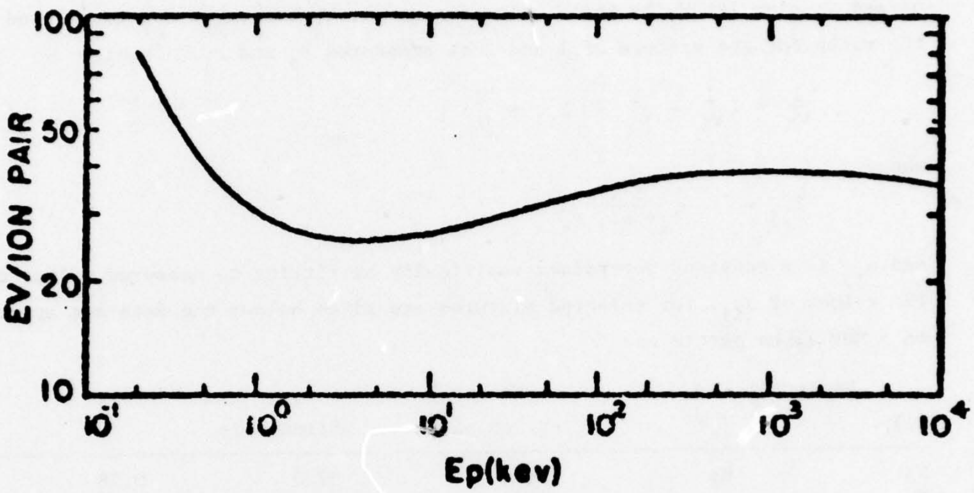
and a_{ij} is a constant determined empirically by fitting to measured values of W_m. The values of a_{ij}, for selected mixtures are given below; the data are appropriate to 5 MeV alpha particles.

Mixture (i)	(j)	W_i eV/ion pair	W_j eV/ion pair	a_{ij}	Refc.
N_2	H_2	36.3	37.0	0.28	i
N_2	Ar	36.3	26.4	0.53	i
N_2	O_2	36.3	32.2	1.06	i
He	Ar	30.1	26.4	0.75	i
He	H_2	29.7	37.0	3.55	i
He	N_2	29.7	36.3	8.47	i
He	CH_4	30.3	29.4	0.68	i
H_2	Ar	37.0	26.4	1.78	i
H_2	CH_4	37.0	29.4	4.03	i
C_2H_2	N_2	27.8	36.3	0.26	i
C_2H_2	CO_2	27.8	34.3	0.93	i
C_2H_2	CH_4	27.8	29.4	0.39	i
CH_4	N_2	39.4	36.3	0.62	i
C_2H_2	He	27.8	30.3	0.058	i
Ar	H_2	26.4	37.00	2.19	ii
Ar	Kr	26.4	24.04	0.412	ii
Ar	CO_2	26.4	34.45	0.637	ii
Ar	CO	26.4	34.77	0.877	ii
Ar	CH_4	26.4	29.26	0.487	ii
Ar	N_2O	26.4	34.43	0.521	ii
Ar	O_2	26.4	32.20	0.817	ii

Note: The data from Hurst, et al., (i.e. all data with Ar listed as species (i)) do not accurately fit the sample equation given above due to the influence of excited Ar*. A more complex representation, giving a better fit to the data is to be found in Hurst, et al.

Reference: (i) G. S. Hurst and T. D. Strikler, Publication 725, National Academy of Sciences - National Research Council, 134, 1960.

(ii) G. S. Hurst, et al., J. Chem. Phys. 42, 713 (1965).

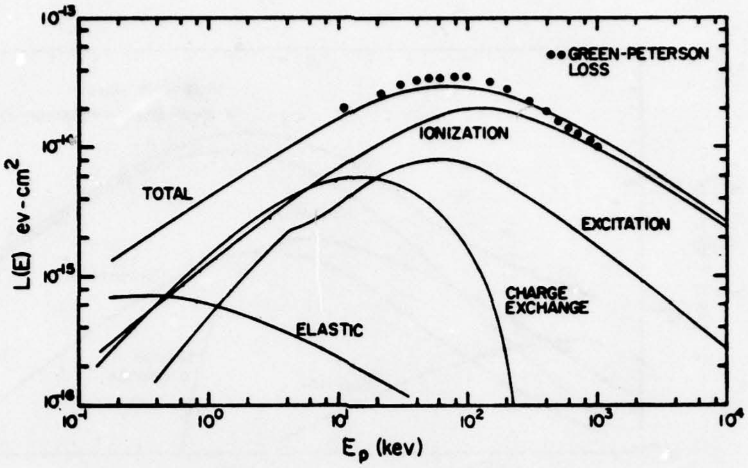


Graphical Data G-4.4. Energy to create an ion pair as a function of projectile energy.

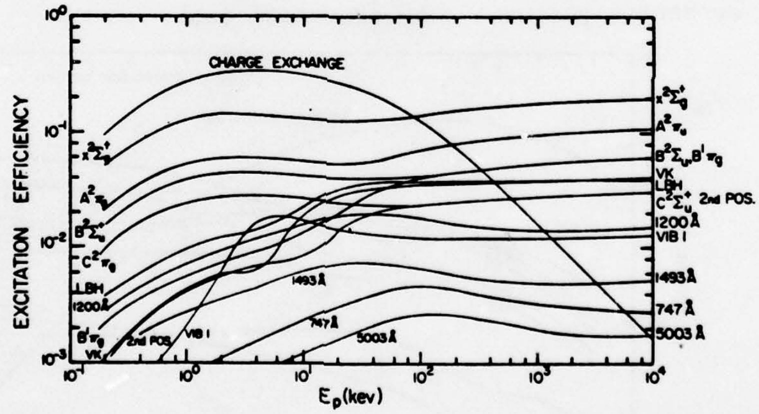
Note: The energy to create an ion pair, W, displayed on G-4.1 through G-4.3 represents the result of a high impact energy measurement. The value of W must be a function of projectile energy although this dependence is not often studied. The graph (which shows the electron volts energy lost per ion pair produced by H^+ at energy E_p traversing N_2) gives a theoretical prediction of W, based in part on experimental cross section behaviour, shown as a function of proton energy (E_p) for H^+ traversing N_2.

Reference: B. C. Edgar, et al., J. Geophys. Res. 78, 6595 (1973.)

Graphical Data G-4.5. Energy loss pathways for high energy protons in high density N_2.



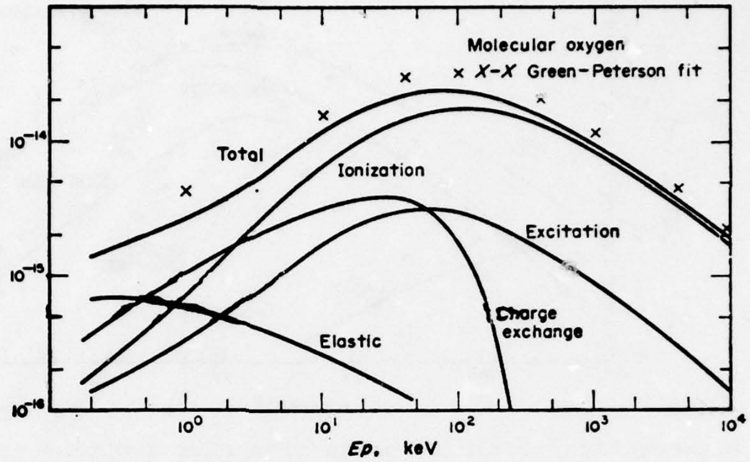
(a) A theoretical estimate of an effective stopping cross section for loss of energy by various mechanisms (as indicated) as a function of projectile energy. Multiplication of stopping cross section L(E) by target density (molecules/cm^3) gives the rate of energy deposition in terms of energy lost (eV) in a mechanism per unit path traversed (cm).



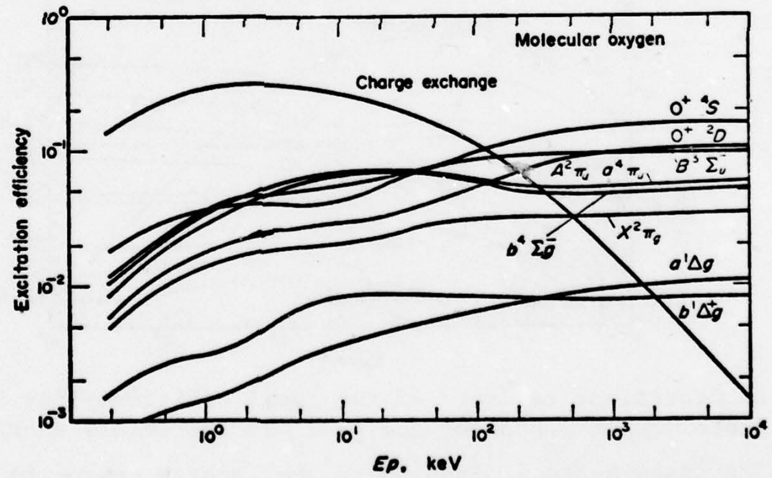
(b) A theoretical estimate of the total efficiency for exciting a state when a proton of energy E_p is completely degraded as it traverses N_2 gas. Thus, a 10^4 keV proton coming to rest deposits 0.2 of its energy (20%) in the $X^2\Sigma g^+$ state (ground state) of N_2^+ and about 0.04 (4%) into the electronic states leading to the Vegard Kaplan bands of N_2 (V-K).

Reference (both graphs): B. C. Edgar, W. T. Miles, and A. E. S. Green, J. Geophys. 78, 6595 (1973).

Graphical Data G-4.6. Energy loss pathways for high energy protons in high density O_2.



(a) A theoretical estimate of an effective stopping cross section for loss of energy by various mechanisms (as indicated) as a function of projectile energy. Multiplication of stopping cross section L(E) by target density (molecules/cm^3) gives the rate of energy deposition in terms of energy lost (eV) in a mechanism per unit path traversed (cm).



(b) A theoretical estimate of the total efficiency for exciting a state when a proton of energy E_p is completely degraded as it traverses O_2 gas. Thus, a 10^4 keV proton deposits 0.1 of its energy (10%) in forming the ^2D state of O^+.

Reference (both graphs): B. C. Edgar, H. S. Porter, and A. E. S. Green, Planet. and Space Sci., 23, 787 (1975).

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COMPILATION OF DATA RELEVANT TO NUCLEAR PUMPED LASERS. VOLUME V--ETC(U)
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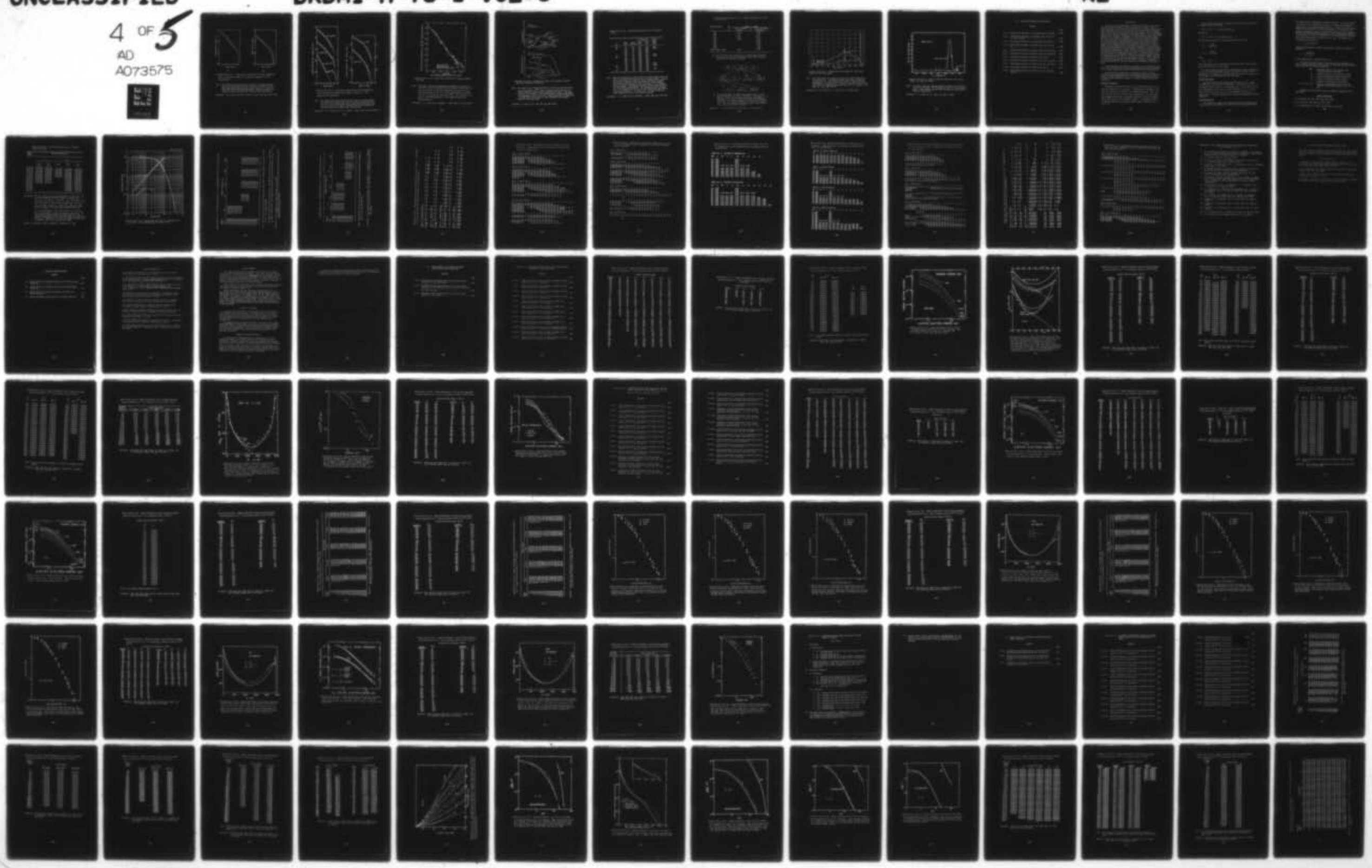


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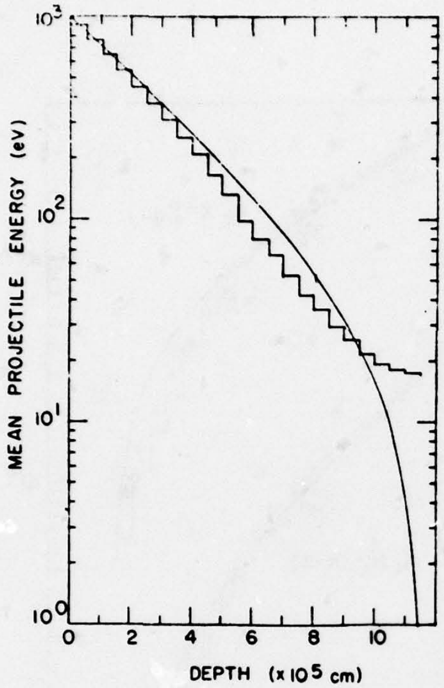

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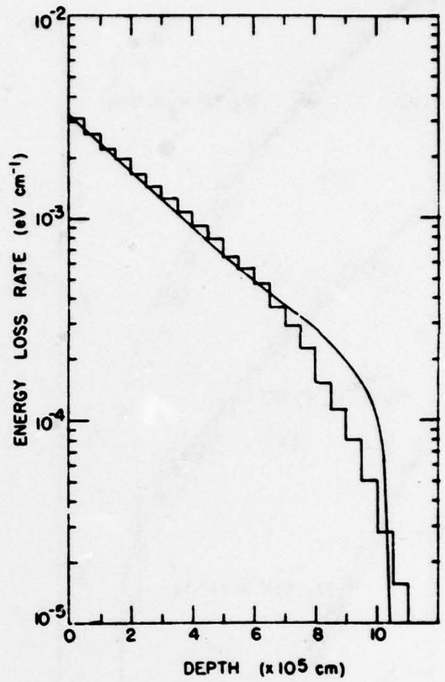
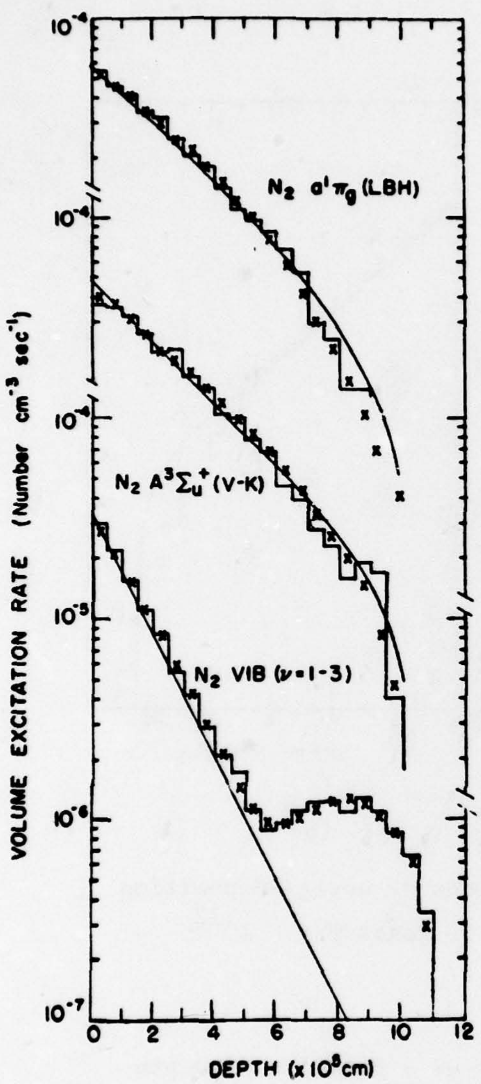


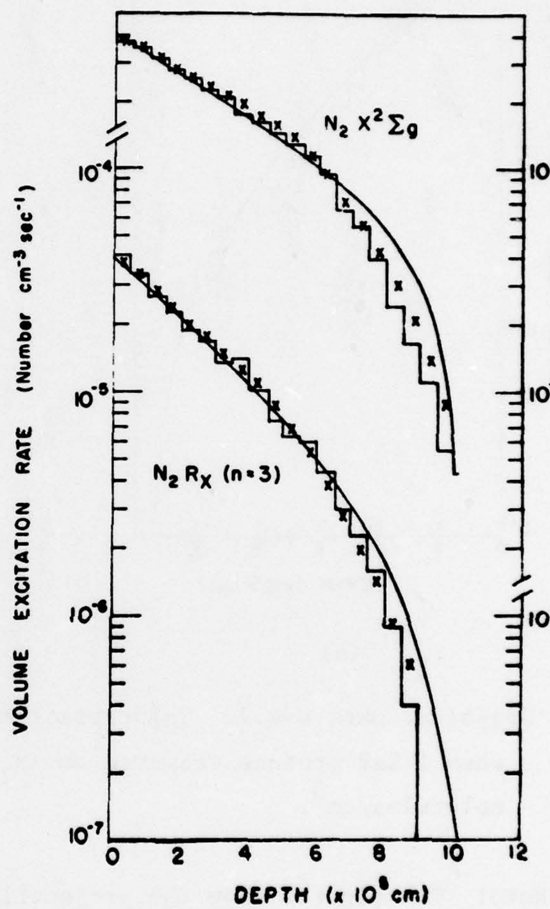
(b)

Graphical Data G-4.7. Theoretical computations of energy deposition when 1 keV protons traverse an N_2 target of density 1×10^{12} molecules/cm^3.

Note: The figures show the projectile energy as a function of depth (Fig. a) and the energy loss as a function of depth (Fig. b); the volume excitation rates for certain states as a function of depth are shown on the following page. The more accurate calculation is the continuous line (a Monte Carlo calculation).

Reference: H.S. Porter, and A.E.S. Green, J. Appl. Phys. 46, 5035 (1975).

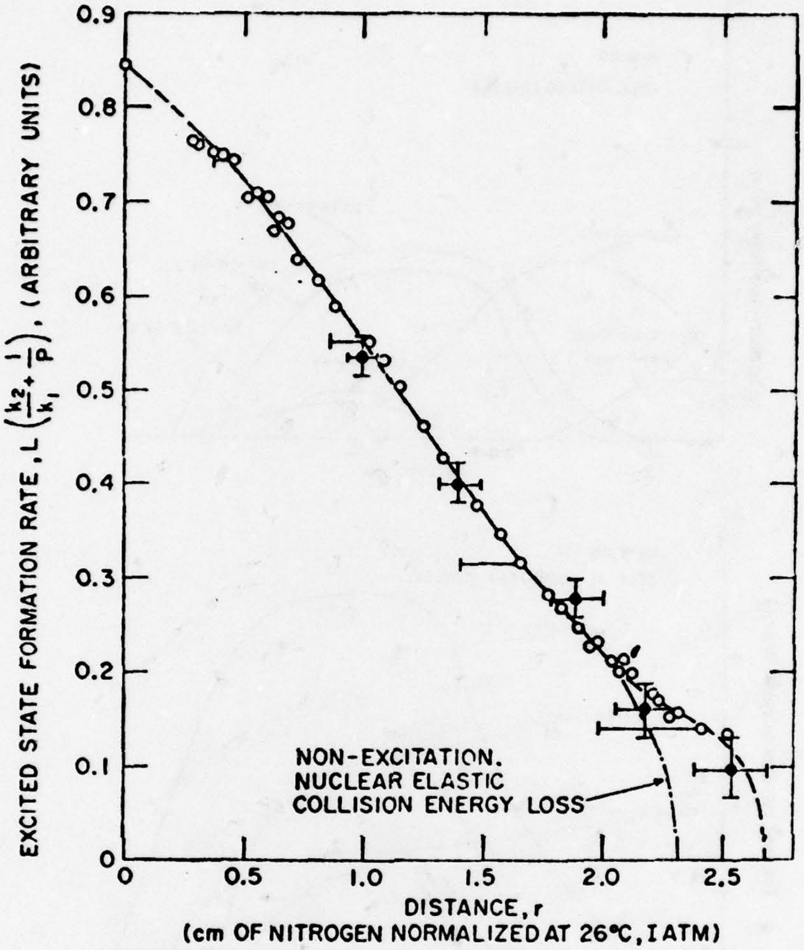




Graphical Data G-4.7. Theoretical computations of energy deposition when 1 keV protons traverse an N_2 target of density 1×10^{12} molecules/cm^3 (Continued).

Note: The figures show the volume excitation rates of certain states as a function of depth; they are to be read in conjunction with the data of the previous page which shows projectile energy loss rate as a function of depth. The more accurate calculation is the continuous line (a Monte Carlo calculation).

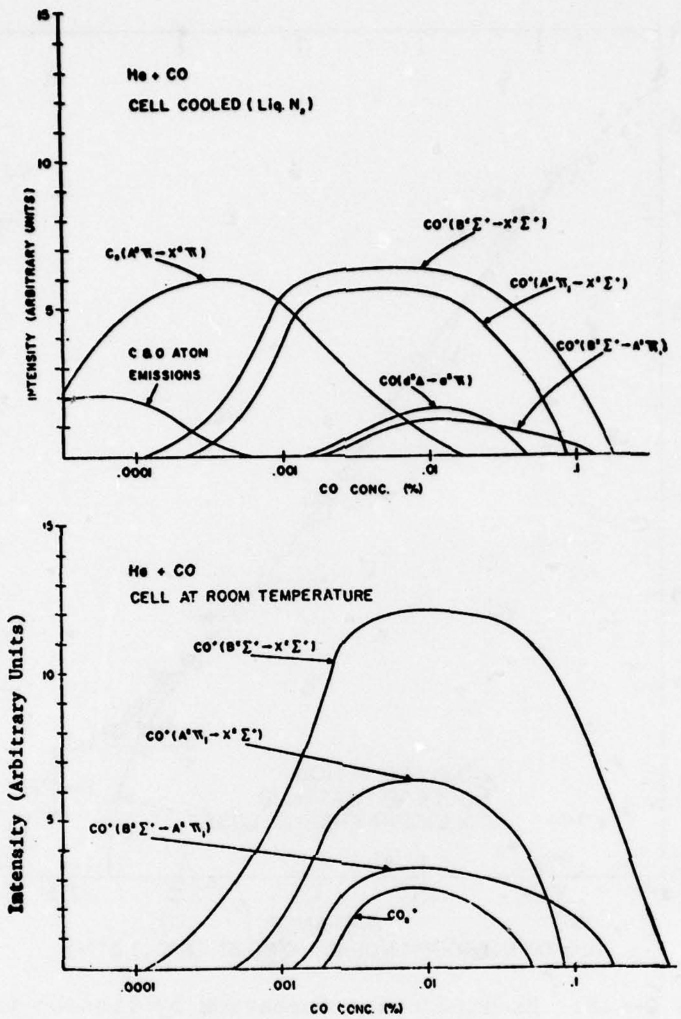
Reference: H. S. Porter and A. E. S. Green, J. Appl. Phys. 46, 5035 (1975).



Graphical Data G-4.8. Excited state formation by fission fragments in N_2 gas.

Note: The figure shows the experimental measurement of the rate of formation of excited N_2 when fission fragments traverse N_2; the data are shown as a function of penetration distance into N_2. The excited state is the C $^3\Pi_u$ state (detected by its luminescence). The radioactive source was ^{252}Cf. The distance is for N_2 at 1 atm pressure and 26°C. The formation rate is in arbitrary units.

Reference: J. T. Sears and R. Rodgers, J. Chem. Phys. 47, 3174 (1967).



Graphical Data G-4.9. Emission of light in the passage of alpha particles through He-CO mixtures.

Note: The figures show relative emission of certain optical lines when α particles (from a Po^{210} source) traverse a He-CO mixture; the data are shown in terms of the percentage CO present. The upper curve is for the gas at -196°C and the lower at room temperature; the difference is said to be due to small quantities of impurities (<0.001%) which are present at room temperature and largely absent in the cooled case.

Reference: C. Kunz et al., Rad. Res. 41, 288 (1970).

Tabular Data G-4.10. Fluorescent efficiencies for excitation of N_2.

Ion	Energy (MeV)	Velocity (10^8 cm/sec)	N_2^+ First negative 3914-Å (0, 0)[a]	Total $v' = 0$[b]	N_2 Second positive Total $v' = 0\text{–}2$[a]
H^+	1.0	13.8	0.67	0.92	(0.79)
N^+	1.45	4.5	0.44	0.60	(0.70)
	2.0	5.3	0.45	0.62	
	3.36	6.9	0.49	0.67	
	3.77	7.2	0.56	0.77	
	5.2	8.3	0.52	0.71	0.78
O^+	2.0	4.8	0.51	0.70	(0.80)
Ne^+	1.0	3.1	0.59	0.81	
	2.0	4.4	0.51	0.70	
	2.85	5.2	0.43	0.59	
	3.7	6.0	0.50	0.68	
	4.75	6.7	0.52	0.71	0.74
	5.1	7.0	0.55	0.75	(0.82)
N_2^+	4.15	5.3	0.44	0.60	0.68
Kr^+	1.65	2.0	0.27	0.37	
	4.8	3.4	0.35	0.47	0.50
O_2^+	5.07	5.5	0.48	0.66	

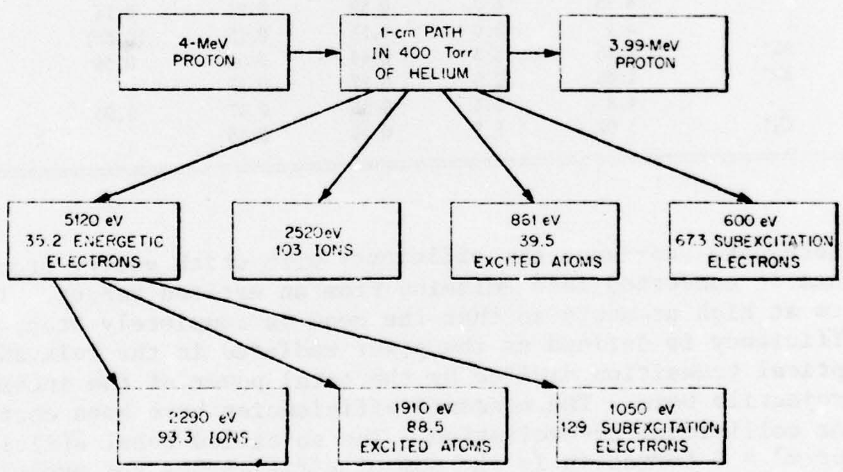
Note: These data represent the efficiency with which energy from an ion beam is converted into emission from an excited target. Targets are at high pressure so that the beam is completely stopped. Efficiency is defined as the power radiated in the relevant optical transition divided by the total power of the incoming projectile beam. The measured efficiencies have been corrected for collisional de-excitation. The so-called total efficiency for $v' = 0$ formation is the sum of efficiencies for exciting all transitions from the $v' = 0$ level (i.e., the 3914 Å band and other transitions in the first negative system).

Reference: J. L. Dunn and R. F. Holland, J. Chem. Phys. 54, 470 (1971).

Tabular and Graphical Data G-4.11. Energy degradation of 4 MeV protons in He.

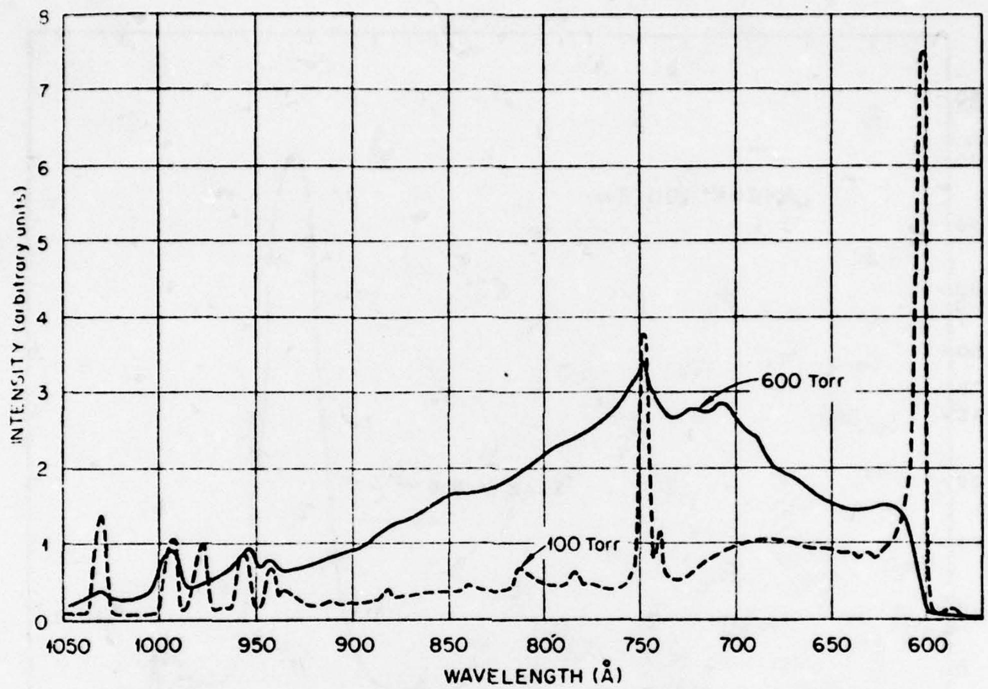
Excited States	Number of Atoms: Due to Primary Protons	Number of Atoms: Due to Secondary Electrons
2^1S	1.40	8.82
3^1S	0.31	1.71
2^1P	25.3	27.6
3^1P	6.24	6.32
3^1D	0.07	1.03
2^3S		16.0
3^3S		1.56
2^3P		8.67
3^3P		1.77
3^3D		1.85
Other atomic levels	6.08	13.2

(a) The table shows the distribution of excited atoms among the various states both for the primary proton impact and also created by the secondary electrons.



(b) The diagram shows the energy loss pathways when a 4 MeV proton traverses 1 cm of He at 400 Torr. The energy lost is 9101 eV. The second row boxes show where this energy is deposited (e.g., 5120 eV is used to produce 35.2 energetic electrons). The third represents the second order effects (e.g., the 35.2 energetic electrons produce 9313 secondary ions, requiring 2290 eV of energy).

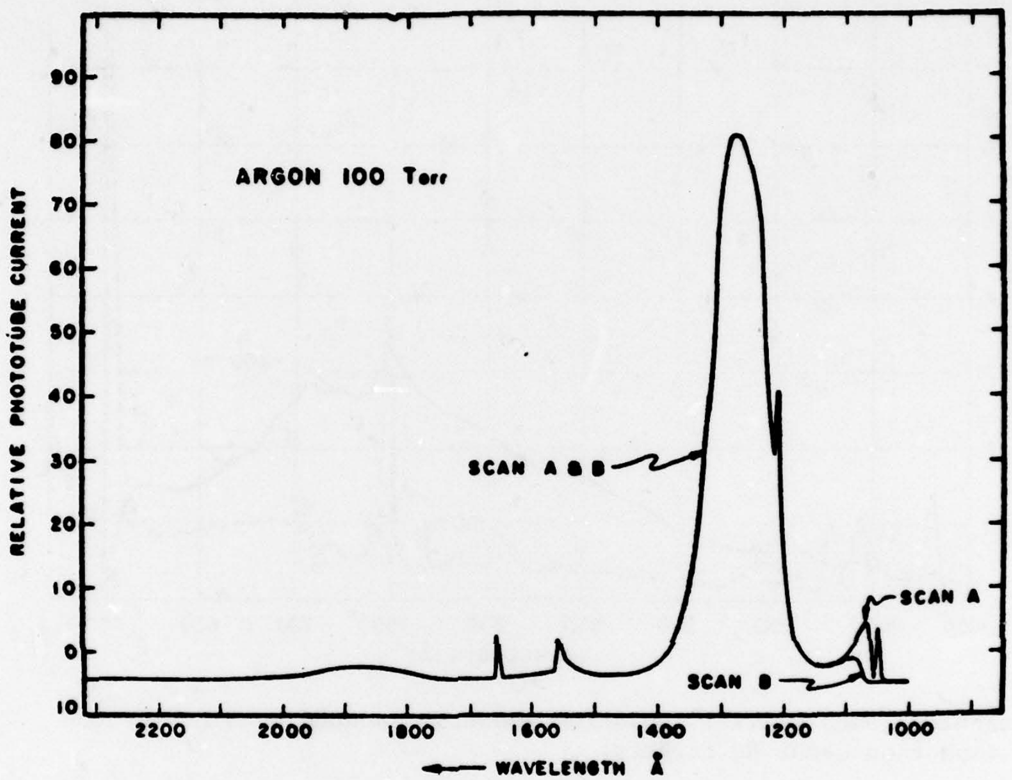
Reference: D. M. Bartell et al., Phys. Rev. A 7, 1068 (1973).



Graphical Data G-4.12. Emission spectrum induced by 4 MeV proton impact on dense He targets.

Note: The figure shows the emission from He with target pressures of 100 and 600 Torr. The higher pressure case clearly shows the development of a continuum which is related to dimer formation. Measurements of intensity as a function of pressure and time are given in the following reference and also in T. E. Stewart et. al., Phys. Rev. A 3, 1991 (1971).

Reference: D. M. Bartell et al., Phys. Rev. A 7, 1068 (1973).



Graphical Data G-4.13. Emission spectrum induced by 4 MeV proton impact on a dense Ar target.

Note: The figure shows the observed emission spectrum for 4 MeV H^+ in a 100 Torr Ar target. The continuum at 1300 Å is due to argon dimers. This spectrum has not been corrected for variations in detection sensitivity.

Reference: G. S. Hurst et al., Phys. Rev. 178, 4 (1969).

G-5. EQUILIBRIUM CHARGE STATE FRACTIONS

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Introduction

A projectile beam traversing a thick target undergoes many successive collisions resulting in loss or pickup of electrons. After a sufficient number of collisions the distribution of charge states attains some equilibrium value that is related to the various charge changing cross sections but is not related to the gas density, nor to the charge state of the projectiles when they entered the target. These equilibrium fractions are important information for determining how fast projectiles interact with a medium. In general, at a very low projectile energy the cross section for neutralization of an ion (by electron transfer) is very high and the projectile beam will be almost entirely neutral. As projectile energy increases the stripping cross sections become large and the average charge state increases; eventually, at very high energy, the projectile becomes completely stripped to a bare nucleus. In the present compendium we shall restrict ourselves to gaseous targets. Considerable information is also available for beams traversing solids; for these the reader should refer to the compendia by Allison, by Betz, and by Wittkower and Betz referenced below. It should be noted that although there are considerable similarities between different targets, the average charge of a beam in a solid is inherently higher than that of a gas, even if both are the same chemical species. This arises due to the short mean free path in a solid which results in collisions while the projectile is excited; the matter is adequately discussed by Betz.

The charge state distribution of interest is the equilibrium fraction. Some limited data on the nonequilibrium fractions are available in the reviews cited below; none of such data will be considered here.

The description of behaviour is somewhat different for light projectiles such as hydrogen and helium compared with heavy projectiles (such as fission fragments) since for the light projectiles only two or three charge states are possible. We shall introduce these cases separately.

Hydrogen Projectiles

Hydrogen has the three states H^-, H^0, and H^+ giving rise to the fractions denoted $F_{\bar{1}\infty}$, $F_{0\infty}$, and $F_{1\infty}$. Stripping of H^- exhibits a very high cross section so if formed it is readily destroyed. Thus, in no case has the observed H^- fraction $F_{\bar{1}\infty}$ exceeded 0.02. For any target gas, hydrogen projectiles at energies less than 10 keV are primarily (about 80%) neutral, the remainder being H^+. For energies of about 500 keV and higher, the projectile beam becomes at least 99% H^+, so $F_{1\infty} \simeq 1.0$.

If we neglect the small H^- component, then the processes governing the charge state are stripping

$$H^0 + X \rightarrow H^+ + X + e \text{ (cross section } \sigma_{01})$$

and capture

$$H^+ + X \rightarrow H^0 + X^+ \text{ (cross section } \sigma_{10}) \quad .$$

The equilibrium fractions of neutrals and ions are given by

$$F_{0\infty} = \frac{\sigma_{10}}{\sigma_{10} + \sigma_{01}}$$

$$F_{1\infty} = \frac{\sigma_{01}}{\sigma_{10} + \sigma_{01}}$$

where

$$F_{0\infty} + F_{1\infty} = 1. \quad .$$

Thus, $F_{0\infty}$ and $F_{1\infty}$ can be calculated from the individual cross sections given in Section B-2 of this volume.

We shall present in this section representative direct measurements of $F_{0\infty}$, $F_{1\infty}$, and the negative fraction $F_{\bar{1}\infty}$ (where available and non-negligible). The reader can generate values for other cases using data for σ_{01} and σ_{10} from Section B-2, where available.

Helium Projectiles

The three relevant charge states are He^0, He^+ and He^{2+}, giving fractions $F_{0\infty}$, $F_{1\infty}$, and $F_{2\infty}$, respectively. Clearly $F_{0\infty} + F_{1\infty} + F_{2\infty} = 1$. At energies below 10 keV, $F_{2\infty}$ is negligible, $F_{1\infty}$ is less than 0.1, and $F_{0\infty}$ predominates at about 0.9. At about 500 keV, $F_{0\infty}$ is 0.1 or less and at 5 MeV or so $F_{0\infty}$ and $F_{1\infty}$ are both negligible so that $F_{2\infty}$ is almost unity. The data presented here are direct measurements of these fractions.

Heavy Projectiles

The equilibrium charge state distributions have been measured for many projectiles at energies up to 150 MeV. The data reproduced here

are taken from the compendium by Wittkower and Betz. F_q is the fraction of the beam in the charge state q and $\sum_q F_q = 1$ where the summation is taken from q = 0 (a neutral projectile) to q = Z (where Z is the nuclear charge and the projectile is totally stripped). In the tables, F_q is given as a percentage; thus, if a beam has a fraction 0.10 in a charge state 5 then under a column heading of 5+ there is placed the number 10. In some cases F_q plotted as a function of q is approximately a Gaussian about some average value $\bar{q}$ defined as $\bar{q} = \sum_q q F_q$. The width of the distribution is d given by

$$d = \sum_q [(q-\bar{q})^2 F_q]^{1/2}$$

Often the distribution is skewed towards high q values and skewness is defined as

$$S = \sum_q \frac{(q-\bar{q})^3 F_q}{d^3} .$$

If the distribution is Gaussian then S = 0.

The tables for heavy ions are taken directly from Wittkower and Betz. The projectile and target are clearly indicated and the following symbols head the columns of information:

REF	=	Reference number of the original paper (references given at the end)
E	=	Indicate energy of the projectile in MeV.
QB	=	Average equilibrium charge $\bar{q}$ (see above).
D	=	Width of distribution d (see above).
S	=	Skewness of distributions (see above).
0+, 1+, 2+, etc.	=	Heads the column giving the fraction (in percent) of the beam in state q = 0, +1, +2, etc.

Fractions are omitted where they are negligible (generally less than 0.1%).

General References

S. K. Allison, Rev. Mod. Phys. 30, 1137 (1958).

H. D. Betz, Rev. Mod. Phys. 44, 465 (1972).

A. B. Wittkower and H. D. Betz, Atomic Data 5, 113 (1973).

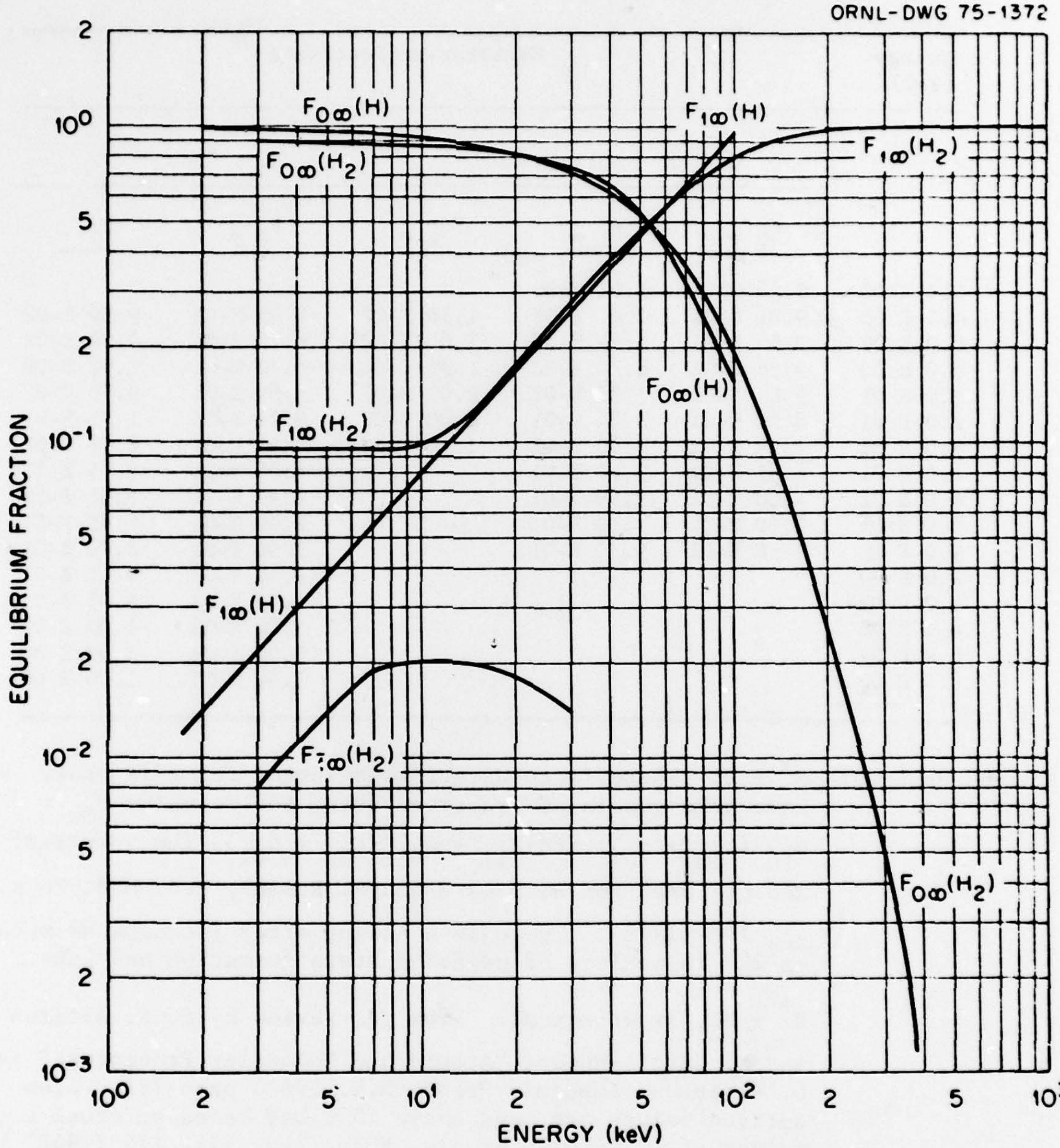
Tabular Data G-5.1. Equilibrium fractions of a hydrogen beam in H and H_2.

Energy (keV)	Equilibrium Fractions				
	H		H_2		
	$F_{0\infty}$	$F_{1\infty}$	$F_{\bar{1}\infty}$	$F_{0\infty}$	$F_{1\infty}$
2.0 E 00	9.86 E-01	1.41 E-02			
4.0 E 00	9.71 E-01	2.91 E-02	1.10 E-02	8.95 E-01	9.50 E-02
6.0 E 00	9.54 E-01	4.54 E-02	1.64 E-02	8.75 E-01	9.50 E-02
8.0 E 00	9.36 E-01	6.30 E-02	1.95 E-02	8.70 E-01	9.50 E-02
1.0 E 01	9.24 E-01	7.85 E-02	2.00 E-02	8.65 E-01	9.70 E-02
2.0 E 01	8.12 E-01	1.68 E-01	1.80 E-02	8.20 E-01	1.75 E-01
3.0 E 01	7.33 E-01	2.60 E-01	1.40 E-02	7.25 E-01	2.75 E-01
4.0 E 01	6.61 E-01	3.50 E-01		6.25 E-01	3.80 E-01
6.0 E 01	4.00 E-01	5.50 E-01		4.40 E-01	5.40 E-01
8.0 E 01	2.50 E-01	7.50 E-01		2.90 E-01	6.85 E-01
9.0 E 01	1.52 E-01	9.50 E-01		1.90 E-01	8.20 E-01
2.0 E 02				2.40 E-02	9.75 E-01
3.0 E 02				5.25 E-03	9.95 E-01
4.0 E 02				1.20 E-03	1.00 E 00
6.0 E 02				1.60 E-04	1.00 E 00
8.0 E 02				5.40 E-05	1.00 E 00

References: $H^+ + H$: There is no direct measurement for this case. We have here generated fractions using the formulae $F_{0\infty} = \sigma_{10}/(\sigma_{10} + \sigma_{01})$ and $F_{1\infty} = \sigma_{01}/(\sigma_{10} + \sigma_{01})$, the values of σ_{01} and σ_{10} are from H. Tawara and A. Russek, Rev. Mod. Phys. 45, 178 (1973). There is a slight error (perhaps as much as 2%) in neglect of negative state formation and loss.

$H^+ + H_2$, Experimental: From the review by S. K. Allison and M. Garcia-Munoz, "Atomic and Molecular Processes," (ed. D. R. Bates, Academic Press, N.Y. 1962) page 721. Also derived values are used above 1000 keV based on cross section values of L. Toburen et al., Phys. Rev. 171, 114 (1968) and U. Schryber, Helv. Phys. Acta 39, 562 (1966).

Accuracy: Systematic error is negligible. Random error $< \pm 5\%$.



Graphical Data G-5.1. Equilibrium fractions for a hydrogen beam in H and H_2. (See preceding page for tabular data.)

Tabular Data G-5.2. Equilibrium fractions of a hydrogen beam in Ne, Kr, CO, CO_2, and H_2O.

Energy	Neutral Fraction $F_{0\infty}$				
keV	Ne	Kr	CO	CO_2	H_2O
4.0 E00	6.42 E-01				
7.0 E00	6.87 E-01				
1.5 E01	6.32 E-01				
2.0 E01	5.77 E-01				
3.0 E01	4.73 E-01				
4.0 E01	4.05 E-01				
6.0 E01	3.29 E-01				
8.0 E01	2.73 E-01				
1.0 E02	2.27 E-01	1.9 E-01	1.7 E-01	2.0 E-01	1.7 E-01
2.0 E02		2.1 E-02	3.6 E-02	4.6 E-02	3.6 E-02
3.0 E02		6.0 E-03	1.1 E-02	1.5 E-02	1.2 E-02
4.0 E02		4.8 E-03	4.0 E-03	6.0 E-03	4.0 E-03
5.5 E02		3.2 E-03	2.0 E-03	2.2 E-03	1.4 E-03
8.0 E02			6.0 E-04	6.2 E-04	6.0 E-04
1.0 E03			4.0 E-04	4.0 E-04	3.0 E-04
1.5 E03			1.6 E-04	1.3 E-04	1.3 E-04
2.0 E03			6.7 E-05	7.3 E-05	5.7 E-05
2.5 E03			3.6 E-05	3.8 E-05	3.4 E-05

Note: Data for He, Ar, N_2, and O_2 targets have been given in both tabular and graphical form in Vol. II on pages 816-819.

We present only the neutral fraction $F_{0\infty}$. The negative ion fraction $F_{\bar{1}\infty}$ is negligible for most of these data. The positive ion fraction $F_{1\infty}$ may be calculated from $F_{1\infty} = 1 - F_{0\infty}$.

References: S. K. Allison, Rev. Mod. Phys. 30, 1137, (1958).
L. H. Toburn, M. Y. Nakai, and R. A. Langley, Oak Ridge National Laboratory Report ORNL-TM-1988 (November 1967).

Tabular Data G-5.3. Equilibrium fraction of a helium beam in Ne and Kr.

Energy keV	Ne $F_{o\infty}$	Ne $F_{1\infty}$	Ne $F_{2\infty}$	Kr $F_{o\infty}$	Kr $F_{1\infty}$	Kr $F_{2\infty}$
8.0 E00	9.82 E-01	1.80 E-02				
2.0 E01	9.40 E-01	6.00 E-02				
4.0 E01	8.35 E-01	1.64 E-02	1.2 E-03			
6.0 E01	7.45 E-01	2.51 E-02	1.4 E-03			
8.0 E01	6.72 E-01	3.20 E-01	7.8 E-03			
1.0 E02	6.09 E-01	3.79 E-01	1.2 E-02			
2.0 E02	4.14 E-01	5.51 E-01	3.5 E-02			
3.0 E02				1.40 E-01	7.80 E-01	8.00 E-02
6.7 E02				1.40 E-02	4.91 E-01	4.95 E-01
1.3 E03				6.00 E-04	1.62 E-01	8.37 E-01
2.8 E03				1.00 E-04	7.6 E-02	9.24 E-01
5.9 E03					1.6 E-02	9.84 E-01

Note: Data for He, Ar, H_2, N_2, O_2 targets have been given in both tabular and graphical form in Vol. II pages 820-825.

References: S. K. Allison, Rev. Mod. Phys. 30, 1137 (1958). P. Hvelplund, E. H. Pedersen, Phys. Rev. A. 9, 2434 (1976). V. S. Nikolaev et al., Soviet Physics JETP, 12, 627 (1961).

Tabular Data G-5.4. Equilibrium fractions of selenium in O_2, Ar, Kr, and Xe. (Reproduced from the compilation by Wittkower and Betz, see Introduction.)

TABLE 21. 1. SELENIUM IN OXYGEN GAS

REF	E	QB	D	S	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+
81	16.0	6.97	1.53	.639	.330	.241	2.54	11.1	27.6	26.8	16.9	8.76	3.49	1.72	.603	.151	.040		
81	18.0														.820	.260	.065	.012	.001

TABLE 21. 2. SELENIUM IN ARGON GAS

REF	E	QB	D	S	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+
81	16.0	7.06	1.59	.797	.020	.170	2.08	10.6	27.9	26.2	16.5	8.75	4.30	2.17	.721	.340	.130				
81	18.0														.869	.370	.150	.050	.010	.002	.4-3

TABLE 21. 3. SELENIUM IN KRYPTON GAS

REF	E	QB	D	S	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+
81	14.0	6.35	1.55	.804	.040	.750	7.67	21.3	30.8	19.9	10.4	5.25	2.27	1.05	.420	.160	
81	16.0	6.96	1.65	.887		.220	2.85	12.5	28.9	24.7	15.3	7.86	4.05	2.05	.950	.390	.190

					3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+	19+	20+
81	18.0	7.19	1.56	1.09	.150	1.02	7.17	28.3	27.7	20.4	7.52	4.09	2.08	.948	.459	.160	.092	.028	.010	.003	.7-3	.1-3

TABLE 21. 4. SELENIUM IN XENON GAS

REF	E	QB	D	S	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+	19+	20+
81	14.0	6.91	1.47	.671	.104	2.47	11.5	28.8	27.5	16.3	7.94	3.26	1.34	.511	.140							
81	16.0	7.47	1.57	.949	.030	.640	5.34	22.1	29.1	21.5	11.5	5.47	2.48	1.09	.440	.220	.080	.046	.007	.001	.001	.6-3
81	18.0	7.98	1.60	.875	.020	.190	2.04	13.4	27.0	25.7	16.5	8.13	4.02	1.77	.750	.330	.130	.050	.013	.004	.8-3	

Tabular Data G-5.5. Equilibrium fractions of bromine in H_2, He, N_2, and O_2. (Reproduced from the compilation by Wittkower and Betz, see Introduction.)

TABLE 22. 1. BROMINE IN HYDROGEN GAS

REF	E	QB	D	S	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+
94	2.00	1.46	.030	.402	9.89	45.1	35.5	8.34	1.06	.100								
94	4.00	2.01	.909	.350	2.85	25.9	44.6	21.6	4.36	.560	.060	.010						
94	6.00	2.43	.762	-.21	.557	10.1	39.9	45.4	3.59	.379	.047							
94	8.00	3.29	.966	.288		1.69	18.3	41.0	29.2	8.61	1.07	.150	.030					
94	10.0	3.95	.988	.217		.270	5.18	26.8	40.4	22.0	4.41	.771	.080					
94	12.0	4.70	.983	.220		.020	.673	8.50	33.3	39.0	14.7	3.45	.290	.040				
29	13.9	4.70	1.05	.371			.620	10.2	33.0	36.6	14.7	4.15	.620	.090	.020			
94	14.0	5.29	.985	.198		.010	.040	2.27	17.2	41.6	27.8	9.74	1.12	.120				
29	25.0	7.21	1.08	.245					.250	4.39	20.0	38.0	27.0	8.49	1.60	.390	.060	.012

TABLE 22. 2. BROMINE IN HELIUM GAS

REF	E	QB	D	S	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+
94	2.00	2.25	.994	.373	2.11	19.5	41.4	27.1	8.12	1.56	.200	.020						
94	4.00	2.64	1.07	.413	.920	11.5	34.9	33.7	14.3	3.80	.730	.130	.010					
94	6.00	3.17	1.12	.402	.220	4.44	23.2	36.9	24.1	8.66	1.98	.420	.050	.020				
94	8.00	2.74	1.13	.391	1.12	11.1	30.0	36.0	15.6	4.71	1.19	.200	.050					
94	10.0	4.32	1.17	.346		.240	3.94	19.8	34.7	27.0	10.4	3.32	.540	.120				
94	12.0	4.82	1.20	.272		.050	1.27	11.2	27.7	33.6	17.7	7.09	1.23	.180	.050			
29	13.9	4.86	1.20	.404			.999	10.2	29.0	34.5	15.0	8.49	1.70	.200	.030			
94	14.0	5.38	1.17	.238		.010	.240	3.63	18.2	34.8	25.7	13.6	3.08	.430	.090			
29	25.0	7.12	1.21	.284					.657	7.58	21.2	34.9	24.2	8.59	2.22	.505	.121	.020
56	100.	15.7																
56	140.	19.0																

TABLE 22. 3. BROMINE IN NITROGEN GAS

REF	E	QB	D	S	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+
94	2.00	2.20	1.18	1.08	2.55	25.3	39.8	20.7	7.12	2.85	1.04	.460	.110	.020							
94	4.00	3.10	1.39	.986	.330	7.32	29.2	32.1	17.0	7.74	3.49	1.92	.670	.200							
94	6.00	4.06	1.58	.846	.040	1.46	11.2	27.2	27.5	16.2	7.86	5.17	2.09	.890	.300	.080					
94	8.00	4.85	1.63	.663		.270	3.71	15.5	27.8	23.0	13.5	9.31	4.26	1.75	.700	.180					
94	10.0	5.44	1.62	.684		.030	.850	7.42	22.6	26.2	19.0	13.2	6.27	2.66	1.19	.390	.120	.040			
94	12.0	6.03	1.62	.621			.140	2.68	13.4	25.0	23.4	18.8	9.26	4.33	1.94	.730	.240	.070			
94	14.0	6.45	1.58	.671			.040	.850	7.19	21.5	25.1	23.4	12.0	6.06	2.27	1.00	.400	.120	.070		
30	20.0	7.20	1.56	.507					1.92	10.9	20.7	28.5	19.7	10.0	5.10	2.16	1.00				
30	25.0	8.52	1.60	.541						1.13	5.85	21.0	27.1	20.7	12.6	6.67	3.38	1.66			
30	41.7	11.2	1.72	.377								.390	3.20	11.4	21.2	23.3	18.5	11.7	6.23	2.80	1.29

REF	E	QB	D	S	11+	12+	13+	14+	15+	16+	17+	18+	19+	20+	21+	22+	23+
30	100.	16.1	1.59	.106	.090	.760	3.26	10.3	20.1	25.2	20.8	12.7	4.77	1.55	.460		
30	140.	17.6	1.64	.204			.330	2.00	7.17	16.6	23.4	23.4	15.3	7.70	2.82	1.01	.270

TABLE 22. 4. BROMINE IN OXYGEN GAS

REF	E	QB	D	S	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+
94	2.00	2.42	1.23	.887	2.07	19.6	37.0	25.6	9.73	3.97	1.32	.530	.140	.020							
94	4.00	3.28	1.44	.871	.290	6.23	24.9	32.3	19.2	9.40	4.39	2.27	.780	.270							
94	6.00	4.06	1.58	.871	.050	1.40	11.9	27.8	26.4	16.3	8.22	4.62	2.01	.870	.340	.130					
94	8.00	4.80	1.68	.662		.300	4.61	17.7	25.8	21.8	13.8	9.35	4.09	1.70	.649	.200	.070				
94	10.0	5.45	1.63	.643		.040	1.02	7.89	21.2	26.7	19.0	13.5	6.24	2.75	1.14	.400	.120	.040			
94	12.0	6.09	1.66	.554			.260	3.27	12.9	23.3	22.7	20.1	9.51	4.71	2.22	.820	.290	.059	.010	.001	[illegible]
94	14.0	6.58	1.61	.570			.040	.791	6.65	19.3	24.0	24.4	13.4	6.41	3.05	1.33	.420	.140			
30	20.0	7.24	1.53	.567					1.85	9.50	19.8	30.4	20.5	10.3	4.55	1.96	.830	.100			
30	25.0	8.35	1.61	.571						1.78	7.57	23.3	26.6	19.4	11.0	5.73	3.22	1.41			
37	28.2	8.56	1.68	.646						2.00	6.19	16.6	30.5	19.5	14.3	4.52	4.19	1.64	.410	.160	.080
30	30.0	9.16	1.60	.550							1.87	12.1	23.6	24.3	18.9	11.0	5.02	2.13	.720	.230	
30	41.7	11.4	1.67	.369								.210	1.97	9.38	19.8	24.5	19.9	12.9	6.91	3.17	1.34

REF	E	QB	D	S	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+	19+	20+	21+	22+	23+	24+
37	55.6	12.2	1.85	.422	.714	3.92	15.7	18.7	21.6	16.9	10.8	6.36	3.61	1.36	.214						
37	67.0	14.0	1.71	.024		.396	1.11	4.98	12.6	18.9	23.4	19.8	10.4	6.22	2.10						
37	82.2	15.0	1.75	.053			.320	1.88	3.89	13.5	16.0	26.9	19.2	8.37	7.66	2.01	.320				

REF	E	QB	D	S	12+	13+	14+	15+	16+	17+	18+	19+	20+	21+			
30	100.	16.5	1.58	.089	.480	2.26	6.99	17.5	24.4	23.9	14.5	6.86	2.52	.570			
37	115.	17.5	1.57	.257		.330	1.51	7.38	17.4	25.7	23.1	15.0	6.23	2.53	.630	.270	
56	140.	18.0															
37	164.	18.9	1.57	.307			.220	.450	4.24	13.6	24.5	25.1	16.6	10.4	3.10	1.36	.450

Tabular Data G-5.6. Equilibrium fractions of bromine in Ne, Ar, Kr, and Xe. (Reproduced from the compilation by Wittkower and Betz, see Introduction.)

TABLE 22. 5. BROMINE IN NEON GAS

REF	E	QB	D	S	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+
30	20.0	7.00	1.58	.523	3.33	13.8	22.1	27.9	17.0	8.79	4.40	1.95	.770				
30	25.0	8.13	1.66	.646		3.16	10.5	25.7	25.4	16.8	9.41	4.64	2.82	1.56			
30	41.7	10.5	1.83	.605			.140	2.23	9.83	20.6	23.4	18.3	11.9	6.86	3.72	1.89	1.14

REF	E	QB	D	S	11+	12+	13+	14+	15+	16+	17+	18+	19+	20+	21+	22+	23+
30	100.	16.2	1.68	.075	.180	1.00	3.99	10.6	19.3	23.5	20.9	12.6	5.50	1.96	.370	.110	
30	140.	18.1	1.63	.085			.120	1.00	3.94	11.2	20.4	23.8	21.0	11.7	4.92	1.50	.430

TABLE 22. 6. BROMINE IN ARGON GAS

REF	E	QB	D	S	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+
94	2.00	1.96	1.04	1.15	3.01	31.2	42.9	16.4	4.17	1.44	.600	.340						
94	4.00	2.96	1.37	1.25	.363	8.30	32.7	32.8	15.1	5.05	2.76	1.72	.776	.322				
94	6.00	3.83	1.57	1.11	.050	1.78	15.4	31.6	25.5	12.9	5.93	3.66	1.85	.870	.320	.150		
94	8.00	4.70	1.66	.974		.210	4.30	19.0	28.6	22.8	11.4	7.18	3.60	1.58	.808	.329	.130	.040
94	10.0	5.43	1.72	.841		.063	.998	8.59	22.5	27.0	17.2	12.5	5.79	2.95	1.52	.649	.290	.090

REF	E	QB	D	S	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+
94	12.0	6.09	1.70	.866	.140	2.22	12.9	26.5	22.7	18.1	8.67	4.54	2.30	1.10	.441	.200	.056	.012	.002	.3-3	.5-4
29	13.9	5.96	1.55	.592		2.76	13.2	27.6	23.6	16.6	9.72	4.56	1.25	.521	.180						
94	14.0	6.66	1.72	.908	.020	.590	5.80	19.9	24.6	23.5	12.7	6.52	3.31	1.68	.820	.330	.140	.060	.030		
30	15.0	6.05	1.44	.336		1.74	11.1	26.7	23.6	21.2	9.93	4.76	1.03								
29	25.0	8.62	1.70	.468			.054	1.29	6.62	18.8	26.2	19.8	12.4	7.91	4.94	2.08					
37	28.2	8.75	1.64	.753				.241	3.84	19.5	26.4	22.5	12.7	8.69	3.72	1.36	.943	.181			
56	41.7	11.6	1.56	.275							1.20	6.99	17.0	25.0	23.0	15.0	7.98	2.99	.998		

REF	E	QB	D	S	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+	19+	20+	21+	22+	23+	24+
37	55.6	13.0	1.78	.353	1.04	5.27	13.0	21.0	23.3	16.2	9.93	7.37	1.82	.561	.401					
56	60.0	13.9	1.70	.214	.201	1.51	6.04	15.1	22.1	22.7	19.1	9.06	4.03	1.51	.503	.131				
37	82.2	14.9	1.65	.301	.040	.110	1.08	4.64	13.8	22.4	23.8	19.4	8.06	4.72	1.37	.379	.180	.040		
30	100.	16.0	1.63	.212			.167	.932	4.33	11.6	21.5	25.3	19.4	16.3	4.22	1.50	.747			
37	115.	17.0	1.48	.312						3.48	11.7	22.1	28.4	19.7	9.20	3.48	1.99			
30	140.	17.7	1.69	.285					.320	1.91	6.68	15.4	23.5	23.8	15.7	7.45	3.39	1.36	.600	
37	164.	18.2	1.79	.286						1.23	4.00	11.4	23.5	21.6	19.4	11.4	6.83	2.34	.923	.371

TABLE 22. 7. BROMINE IN KRYPTON GAS

REF	E	QB	D	S	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+
94	2.30	1.60	.948	1.42	6.42	44.6	37.1	8.61	1.88	.788	.379	.180	.050					
94	4.30	2.45	1.28	1.48	1.17	18.0	41.6	25.1	7.95	2.87	1.60	1.12	.510	.160				
94	6.90	3.42	1.52	1.30	.130	4.91	20.2	37.2	20.8	7.57	4.05	2.67	1.35	.691	.250	.100		
94	8.30	4.23	1.68	1.13		.877	8.57	28.7	28.7	14.7	7.98	5.17	2.69	1.64	.998	.239	.080	
94	10.0	5.04	1.76	.935		.123	2.53	14.3	26.9	24.9	12.1	9.46	5.06	2.60	1.25	.508	.209	.080

REF	E	QB	D	S	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+	19+	20+
81	12.0	5.94	1.77	.967	.200	3.72	16.1	26.7	20.6	16.3	8.48	3.98	2.13	.969	.460	.230	.110	.053	.015	.004	.9-3	.1-3	.1-4

REF	E	QB	D	S	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+
94	14.0	6.55	1.73	.938	.030	.760	6.97	21.7	24.3	22.1	12.1	6.16	3.11	1.49	.710	.320	.15[illegible]	.070	.040
30	20.0	7.41	1.48	.646			.720	6.92	18.5	32.2	21.8	11.2	5.13	2.29	.953	.300			
30	25.0	8.53	1.52	.676				.550	4.55	20.8	28.9	22.0	12.7	6.33	2.58	1.15	.400		
30	30.0	9.50	1.60	.617					.680	7.26	20.5	26.2	21.6	12.8	6.52	2.94	1.38	.493	
30	41.7	11.1	1.70	.262						.540	4.02	12.9	21.5	22.8	17.4	11.3	6.36	3.2[illegible]	

REF	E	QB	D	S	10+	11+	12+	13+	14+	15+	16+	17+	18+	19+	20+	21+	22+	23+
30	100.	15.5	1.72	.038	.060	.710	3.24	8.60	16.2	22.6	21.3	15.5	7.77	3.24	.859			
30	140.	17.4	1.71	.276				.690	2.57	9.23	17.3	23.7	21.9	14.1	6.38	2.67	.960	.560

TABLE 22. 8. BROMINE IN XENON GAS

REF	E	QB	D	S	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+	19+	20+
81	12.0	6.42	1.65	.832	.680	1.13	8.17	21.5	24.4	23.3	11.9	5.48	2.09	.996	.548	.259	.129	.042	.012	.003	.9-3	.1-3	.2-4

Tabular Data G-5.7. Equilibrium fractions of krypton in H_2 and He. (Reproduced from the compilation by Wittkower and Betz, see Introduction.)

TABLE 23. 1. KRYPTON IN HYDROGEN GAS

REF	E	QB	D	S	0+	1+	2+	3+	4+
92	.060				61.0				
92	.100				65.0				
92	.150				57.0				
92	.200				52.0				
65	.200	.530	.574	.518	51.0	45.0	4.00		
92	.250				48.0				
65	.300	.650	.589	.282	41.0	53.0	6.00		
65	.400	.775	.612	.171	32.5	57.5	10.0		
65	.500	.866	.665	.359	28.7	56.9	13.4	.990	
65	.600	.990	.714	.344	24.0	55.0	19.0	2.00	
65	.700	1.05	.741	.373	22.0	54.0	21.0	3.00	.020
65	.800	1.12	.758	.376	19.5	53.5	23.0	4.00	.040

TABLE 23. 2. KRYPTON IN HELIUM GAS

REF	E	QB	D	S	0+	1+	2+	3+	4+	5+	6+
92	.100				1.20						
92	.150				2.00						
92	.200				2.40						
65	.200	1.38	.562	.481	2.00	60.0	36.0	2.00			
92	.250				2.90						
65	.300	1.43	.621	.392	3.00	55.0	38.0	4.00			
65	.400	1.45	.662	.408	3.99	52.9	37.9	4.99	.200		
65	.500	1.51	.728	.376	5.02	47.2	40.2	7.03	.602	.020	
65	.600	1.60	.775	.325	5.00	42.0	42.0	10.0	.900	.050	
65	.700	1.68	.812	.263	4.99	37.9	42.9	13.0	1.20	.080	
65	.800	1.73	.833	.209	4.97	34.8	43.7	14.9	1.49	.099	
59	2.95	2.40	1.07	.537	2.01	15.1	42.2	27.1	9.84	3.01	.803

Tabular Data G-5.8. Equilibrium fractions of krypton in N_2, Ne, Ar, and Kr. (Reproduced from the compilation by Wittkower and Betz, see Introduction.)

TABLE 23. 3. KRYPTON IN NITROGEN GAS

REF	E	QB	D	S	0+	1+	2+	3+	4+	5+	6+	7+	8+
65	.200	.890	.598	.324	23.0	66.0	10.0	1.00					
65	.300	1.08	.701	.626	17.1	61.5	18.1	3.02	.202	.040			
65	.400	1.21	.756	.740	13.2	58.1	23.4	4.59	.510	.102	.020		
65	.500	1.32	.814	.757	12.0	52.9	28.0	5.99	.899	.180	.040	.010	
65	.600	1.44	.869	.766	10.0	48.0	32.6	8.00	1.60	.270	.080	.015	
65	.700	1.54	.905	.739	9.00	43.0	36.0	9.50	2.00	.390	.130	.030	
65	.800	1.60	.922	.822	8.00	41.0	38.0	10.0	2.20	.540	.180	.050	.005
59	2.95	2.49	1.28	.662	2.49	17.9	37.8	22.9	9.94	6.96	1.99	.070	

TABLE 23. 4. KRYPTON IN NEON GAS

REF	E	QB	D	S	0+	1+	2+	3+	4+	5+	6+	7+	8+
92	.060				31.0								
92	.100				28.0								
92	.150				24.0								
92	.200				21.5								
65	.200	.890	.581	.320	22.0	68.0	9.00	1.00					
92	.250				20.0								
65	.300	1.03	.699	.485	20.0	60.0	17.0	3.00					
65	.400	1.16	.786	.718	17.1	56.3	21.1	5.02	.402	.151			
65	.500	1.31	.823	.675	13.0	52.1	27.1	7.02	.501	.201	.050		
65	.600	1.42	.892	.654	12.0	46.8	29.9	9.97	.897	.349	.070	.010	
65	.700	1.56	.908	.640	9.02	42.1	35.1	12.0	1.20	.451	.090	.030	.010
65	.800	1.63	.955	.663	8.96	38.8	35.9	13.9	1.49	.697	.139	.050	.012

TABLE 23. 5. KRYPTON IN ARGON GAS

REF	E	QB	D	S	0+	1+	2+	3+	4+	5+	6+	7+	8+
92	.060				57.0								
92	.100				61.0								
92	.150				55.0								
92	.200				51.0								
65	.200	.550	.638	.966	52.0	42.0	5.00	1.00					
92	.250				46.0								
92	.300	.680	.662	.666	42.0	49.0	8.00	1.00					
92	.400	.807	.739	1.12	35.0	52.0	11.0	1.50	.300	.130	.050	.010	
92	.500	.948	.789	1.11	28.1	53.1	16.0	2.00	.501	.190	.090	.018	
92	.600	1.07	.837	1.15	23.0	52.9	20.0	2.99	.798	.259	.120	.028	.007
92	.700	1.15	.867	1.22	19.9	52.8	21.9	3.98	.946	.299	.149	.050	.018
92	.800	1.32	1.01	1.77	15.5	51.4	23.3	7.75	.969	.329	.165	.630	.027

TABLE 23. 6. KRYPTON IN KRYPTON GAS

REF	E	QB	D	S	0+	1+	2+	3+	4+	5+	6+	7+	8+
14	.013				95.2								
14	.016				95.3								
14	.019				95.4								
14	.022				95.6								
92	.060				75.0								
92	.100				69.0								
92	.150				65.0								
92	.200				59.0								
65	.200	.390	.527	.857	63.0	35.0	2.00						
92	.250				53.0								
65	.300	.510	.592	.686	54.0	41.0	5.00						
65	.400	.634	.684	1.26	45.8	46.8	5.98	.996	.299	.060	.020	.008	
65	.500	.730	.732	1.33	40.0	50.0	7.99	1.50	.400	.100	.050	.015	
65	.600	.822	.755	1.29	34.1	53.1	10.5	1.60	.501	.150	.060	.020	
65	.700	.898	.770	1.40	29.1	56.2	12.0	1.81	.602	.191	.080	.030	.010
65	.800	.970	.787	1.47	25.0	57.9	14.0	2.00	.699	.260	.100	.042	.012
59	2.95	1.82	1.12	.817	7.54	35.2	37.2	11.1	6.03	3.02			

Tabular Data G-5.9. Equilibrium fractions of iodine in H_2, He, N_2, and O_2. (Reproduced from the compilation by Wittkower and Betz, see Introduction.)

TABLE 24. 1. IODINE IN HYDROGEN GAS

REF	F	QB	D	S	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+
77	1.05	1.36	.867	.426	14.4	45.1	31.1	8.16	.940	.110				
77	2.95	1.95	.991	.539	4.42	29.4	40.7	19.2	5.15	.990	.110	.040		
76	4.50	2.33	.988	.390	1.51	17.2	42.2	27.8	9.20	1.93	.190			
77	6.00	2.66	1.00	.401	.530	9.26	36.8	35.0	14.4	3.51	.470	.070		
77	8.00	3.20	1.04	.426	.370	2.60	22.3	40.2	24.4	8.60	1.52	.270	.040	
77	10.0	3.57	1.09	.400	.320	1.00	14.1	35.6	30.7	14.4	3.35	.680	.075	.015
77	12.0	4.02	1.12	.334		.290	6.42	26.4	35.5	22.4	7.00	1.77	.200	.020
					14+	15+	16+	17+	18+	19+	20+	21+	22+	23+
56	110.	18.2	1.55	.241	.229	2.71	9.37	21.3	25.0	21.3	12.5	5.31	1.77	.499

THE DATA AT 110 MEV MAY NOT REFLECT COMPLETE CHARGE EQUILIBRIUM.

TABLE 24. 2. IODINE IN HELIUM GAS

REF	E	QB	D	S	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+					
77	1.05	2.44	.876	.351	.430	11.1	44.4	33.8	8.59	1.70										
77	2.95	3.17	1.14	.382		5.06	23.8	35.5	23.4	9.54	2.29	.410								
77	4.90	3.38	1.17	.405	.130	3.17	19.2	35.5	25.8	11.9	3.43	.790	.080							
77	6.00	3.58	1.22	.437	.070	1.99	16.0	33.4	27.4	14.7	4.94	1.36	.190							
77	8.00	4.03	1.29	.475		.680	9.37	28.3	29.6	19.9	8.36	3.11	.590	.100						
77	10.0	4.37	1.34	.401		.280	5.50	21.7	29.2	24.6	12.0	5.30	1.23	.240						
77	12.0	4.77	1.37	.406		.070	2.39	15.4	27.4	27.5	15.7	8.56	2.44	.520	.080					
					11+	12+	13+	14+	15+	16+	17+	18+	19+	20+	21+	22+	23+	24+	25+	26+
56	110.	15.5	1.71	.060	.597	3.13	7.96	16.4	21.4	22.1	16.9	7.46	2.98	.895	.179					
30	162.	19.7	2.14	.130				.200	1.00	4.50	9.50	15.5	16.0	16.0	15.5	12.0	6.00	2.50	1.00	.350

THE DATA AT 110 AND 162 MEV MAY NOT REFLECT COMPLETE CHARGE EQUILIBRIUM.

TABLE 24. 3. IODINE IN NITROGEN GAS

REF	E	QB	D	S	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+	19+
36	15.0	5.66	1.71	.596	8.54	18.7	24.2	18.6	16.7	6.81	3.93	1.56	1.01								
35	59.5	12.8	1.94	.492						.235	1.99	8.18	15.3	23.0	19.9	13.3	8.18	5.32	2.86	1.38	.256
36	60.0	13.1	2.00	.282						.320	1.90	6.13	12.8	18.4	20.2	16.1	11.9	6.96	3.11	1.71	.560
35	72.0	15.6																			
35	85.0	16.8																			
35	100.	18.2																			
					12+	13+	14+	15+	16+	17+	18+	19+	20+	21+	22+	23+	24+	25+	26+	27+	28+
30	110.	17.9	2.02	.436	.080	.468	2.27	6.88	14.2	20.3	19.9	16.0	9.45	5.38	2.85	1.29	.627	.299			
35	116.	19.5																			
35	123.	20.6																			
35	152.	22.0																			
30	162.	21.0	2.18	.097				.160	1.01	3.56	8.30	12.2	15.5	18.1	16.1	11.6	7.55	3.90	1.49	.410	.100

THE DATA AT 110 AND 162 MEV MAY NOT REFLECT COMPLETE CHARGE EQUILIBRIUM.

TABLE 24. 4. IODINE IN OXYGEN GAS

REF	E	QB	D	S	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+
77	1.05	1.99	1.10	.567	5.41	30.5	36.4	18.1	7.00	2.64												
77	2.95	3.19	1.57	.748	.752	9.96	27.5	26.9	15.6	9.99	5.39	2.87	1.09									
77	4.50	3.93	1.75	.809	.160	3.25	17.2	26.9	21.1	13.9	8.09	5.25	2.47	1.17	.500							
77	6.00	4.39	1.82	.831	.050	1.33	10.6	23.9	23.4	17.2	10.1	6.92	3.54	1.83	.800	.330						
77	8.00	5.02	1.93	.794		.330	4.85	17.1	23.4	20.5	13.2	9.54	5.33	3.07	1.64	.740	.320					
77	10.0	5.54	1.98	.741		.110	2.16	11.0	20.4	22.3	16.0	12.4	7.17	4.30	2.30	1.14	.500	.210				
81	12.0	6.16	2.07	.769			.769	5.69	15.0	21.5	18.3	16.1	9.78	5.97	3.46	1.93	.909	.390	.160	.070	.029	.009
					18+	19+	20+															
					.002	.6-3	.6-4															
					5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+	19+	20+	21+	22+
8	12.0						26.0	15.0	8.00	4.00	2.00	1.00	.300									
8	17.4							13.0	8.00	4.00	2.00	1.00	.520	.200	.060	.030	.010	.002				
37	24.8	7.79	1.86	.544	10.3	16.2	22.6	18.9	14.0	9.07	4.98	2.65	1.33									
8	39.3													6.40	3.50	1.70	1.00					
37	51.3	12.2	1.98	.469				.999	6.09	12.8	18.2	21.9	16.6	11.3	9.69	3.40	1.90	1.20				
37	82.8	15.6	2.09	.388						.149	2.95	8.00	15.5	17.6	16.7	16.7	11.1	6.[illegible]4	2.87	1.35	.697	.289
					12+	13+	14+	15+	16+	17+	18+	19+	20+	21+	22+	23+	24+	25+	26+	27+	28+	29+
37	104.	17.5	2.02	.467		1.04	4.02	10.3	17.9	20.3	18.9	12.8	6.84	3.89	2.30	1.43	.301					
30	110.	17.9	2.37	.439	.100	.652	2.48	7.11	14.3	20.2	19.5	15.1	9.43	5.68	2.76	1.62	.73[illegible]	.310				
37	151.	20.8	2.21	.655				.170	.770	2.24	9.63	16.7	20.[illegible]	17.8	12.1	8.13	5.01	3.38	1.99	.880	.300	.190
30	162.	21.1	2.17	.112				.110	1.08	3.29	7.08	14.9	16.6	18.6	14.8	16.9	7.90	4.39	1.60	.580		
37	177.	21.2	2.24	.696					.480	1.98	6.05	14.0	19.5	19.5	14.0	10.6	5.84	3.59	2.09	1.12	.800	.548
37	183.	21.5	2.35	.475					.390	1.56	6.29	11.9	15.9	18.3	15.3	11.1	7.85	5.35	3.23	1.73	.840	.330

Tabular Data G-5.10. Equilibrium fractions of iodine in Ne and Ar. (Reproduced from the compilations by Wittkower and Betz, see Introduction.)

TABLE 24. 5. IODINE IN NEON GAS

REF	E	QB	D	S	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+	19+	
30	15.0	5.58	1.71	.684	9.02	20.0	25.5	18.8	13.1	7.36	3.78	1.59	.930									
30	60.0	12.1	2.11	.423					.408	2.04	6.62	13.0	18.9	19.2	15.8	10.5	6.23	4.27	1.77	.717	.428	
					11+	12+	13+	14+	15+	16+	17+	18+	19+	20+	21+	22+	23+	24+	25+	26+	27+	28+
30	110.	16.7	2.21	.503	.240	1.12	4.02	9.76	15.1	19.8	18.2	13.0	8.41	4.81	2.77	1.34	.930	.530				
30	162.	20.2	2.41	.295				.160	.870	3.66	8.95	13.6	15.0	14.8	14.3	11.2	7.84	5.21	2.60	1.08	.460	.143

TABLE 24. 6. IODINE IN ARGON GAS

REF	E	QB	D	S	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+
77	1.05	1.55	1.04	.783	12.6	41.7	30.0	10.7	3.65	1.32												
77	2.95	2.76	1.42	1.05	1.13	14.1	34.8	26.6	12.4	5.98	2.55	1.66	.790									
77	4.50	3.43	1.60	1.12	.230	5.30	24.4	30.6	19.2	10.3	4.56	2.78	1.43	.770	.380							
77	6.00	3.83	1.66	1.14	.080	2.30	16.8	30.6	23.2	13.5	6.08	3.71	1.90	1.02	.520	.250						
77	8.00	4.56	1.83	1.10		.525	7.15	23.0	26.7	19.1	9.70	6.23	3.45	2.04	1.18	.600	.300					
77	10.0	5.11	1.94	1.04		.170	3.25	15.6	25.0	22.7	13.1	8.78	4.95	3.02	1.74	.937	.529	.249				
81	12.0	5.66	2.06	1.12			1.27	9.30	20.6	25.0	16.2	11.5	6.74	4.16	2.46	1.41	.759	.379	.200	.098	.045	.016
					18+	19+	20+	21+	22+	23+	24+	25+										
					.005	.002	.5-3	.1-3	.2-4	.2-4	.3-5	.3-6										
					1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+					
30	12.0	5.05	1.77	.856	.170	2.95	15.0	24.8	24.2	13.9	9.58	4.66	2.45	1.28	.681	.220						
30	15.0	5.87	1.89	.769		.660	6.18	17.6	23.8	19.4	15.0	7.96	4.81	2.49	1.35	.560	.280					
					8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+	19+	20+	21+	22+	23+	24+	25+
37	51.3	12.3	2.16	.537	1.50	5.61	12.5	20.1	18.6	14.5	11.6	6.11	5.21	2.40	1.30	.501						
30	60.0	13.4	1.94	.189	.142	.912	4.24	10.4	17.8	19.9	17.9	13.3	8.60	4.53	2.31							
37	82.8	16.4	2.08	.254				.310	1.64	5.19	11.2	16.4	20.0	16.8	12.6	8.02	4.35	2.39	1.03			
37	104.	17.4	2.14	.546						.917	7.80	9.20	17.4	20.6	17.5	11.7	6.74	4.06	1.93	1.44	.569	.270
					13+	14+	15+	16+	17+	18+	19+	20+	21+	22+	23+	24+	25+	26+	27+	28+	29+	30+
30	110.	18.3	2.18	.717	.250	1.37	5.07	12.7	19.2	21.0	15.9	10.2	6.00	3.44	2.31	1.42	.781	.401				
37	154.	20.9	2.28	.685			.157	.686	2.94	7.35	16.6	19.6	17.6	13.7	7.83	6.37	2.64	2.15	1.47	.490	.196	.147
30	162.	20.7	2.47	.322			.330	2.00	6.32	11.1	13.4	15.3	16.0	12.3	8.70	6.76	4.14	2.70	1.04	.340		
37	183.	21.5	2.35	.487				.438	2.00	6.22	10.4	14.2	21.2	15.2	11.9	6.73	5.07	3.57	1.65	.887	.322	.136

Tabular Data G-5.11. Equilibrium fractions of iodine in Kr, Xe, and a Hg vapor jet. (Reproduced from the compilation by Wittkower and Betz, see Introduction.)

TABLE 24. 7. IODINE IN KRYPTON GAS

REF	E	QB	D	S	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+
77	1.05	1.20	.931	.692	22.3	45.9	22.8	7.00	1.98													
77	2.95	2.34	1.29	1.04	2.54	23.1	38.2	21.1	8.44	3.78	1.87	1.00										
77	4.50	2.99	1.49	1.24	.650	9.93	32.1	30.0	14.4	6.44	3.07	2.04	.880	.370	.170							
81	6.00	3.36	1.58	1.44	.220	5.02	25.5	32.2	19.6	8.66	3.95	2.59	1.21	.530	.300	.150	.045	.027	.019	.006	.003	.001
					18+	19+	20+	21+	22+													
					.001	.3-3	.9-4	.2-4	.4-5													
					1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+
81	8.00	4.06	1.74	1.43	1.27	12.5	30.4	26.1	13.9	6.60	4.38	2.37	1.31	.645	.288	.149	.072	.029	.023	.013	.007	.002
					19+	20+	21+	22+	23+	24+	25+											
					.001	.3-3	.8-4	.3-4	.1-4	.2-5	.1-5											
					1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+
81	10.0	4.51	1.83	1.46	.468	6.72	24.0	28.3	18.9	8.69	5.91	3.25	1.80	.957	.448	.219	.120	.067	.042	.031	.020	.010
					19+	20+	21+	22+	23+	24+	25+											
					.005	.001	.7-3	.3-3	.1-3	.2-4	.2-5											
					1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+
81	12.0	5.06	1.93	1.34	.120	2.77	15.7	26.6	23.4	12.6	8.22	4.70	2.73	1.49	.767	.399	.199	.110	.067	.040	.020	.012
					19+	20+	21+	22+	23+	24+	25+											
					.007	.003	.9-3	.5-3	.1-3	.3-4	.6-5											
					11+	12+	13+	14+	15+	16+	17+	18+	19+	20+	21+	22+	23+	24+	25+	26+		
81	14.0				.880	.530	.340	.180	.093	.066	.041	.024	.009	.004	.002	.001	.5-3	.1-3	.2-4	.8-6		
					3+	4+	5+	6+	7+	8+	9+	10+	11+									
36	15.0	5.42	1.68	.765	10.6	22.1	26.0	17.6	12.4	5.87	3.66	1.74	.680									
					14+	15+	16+	17+	18+	19+	20+	21+	22+	23+	24+	25+	26+					
81	16.0				.280	.150	.100	.060	.040	.020	.010	.038	.003	.001	.3-3	.7-4	.8-5					
81	18.0					.310	.180	.100	.051	.038	.023	.013	.007	.003	.9-3	.2-3						
					8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+	19+						
36	60.0	13.3	2.01	.290	.253	1.34	5.30	11.1	18.7	19.9	16.9	12.1	7.61	4.13	1.95	.698						
					11+	12+	13+	14+	15+	16+	17+	18+	19+	20+	21+	22+	23+	24+	25+	26+	27+	28+
36	113.	17.3	2.48	.785	.111	.211	2.74	6.98	13.0	17.9	17.9	14.8	9.64	6.00	3.95	2.47	1.65	1.34	.816	.393		
36	167.	19.8	2.63	.583				.250	1.30	5.43	13.6	17.1	14.6	11.6	11.1	8.57	4.09	4.84	2.82	1.49	.800	.370

TABLE 24. 8. IODINE IN XENON GAS

REF	E	QB	D	S	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+
81	12.0	5.25	2.10	1.18	.100	3.09	16.6	23.2	19.6	13.0	10.9	6.41	3.42	1.71	.877	.459	.269	.160	.100	.067	.041	.019
					19+	20+	21+	22+	23+	24+	25+											
					.010	.005	.002	.9-3	.2-3	.8-4	.2-4											

TABLE 24. 9. IODINE IN MERCURY VAPOR JET

REF	E	QB	D	S	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+	19+	20+	21+	22+
34	24.4	8.02	1.66	1.05	16.8	20.2	23.4	14.4	8.76	4.44	2.28	.960	.480	.240							
34	[illegible]	[illegible]	[illegible]	.934	5.81	18.2	26.1	21.2	13.8	6.90	4.14	2.07	.936	.512	.796						
34	38.0	9.81	1.94	.968		7.44	20.2	23.4	18.1	13.3	8.50	4.46	2.12	1.38	.637	.361	.212				
34	46.0	10.9	2.00	.959			9.21	17.3	22.8	19.0	13.5	8.45	4.55	2.49	1.25	.683	.455	.217	.087		
34	54.8	12.[illegible]	2.03	.898				7.58	17.3	22.8	19.5	12.5	8.78	5.42	3.03	1.63	.867	.473	.217		
34	64.3	13.0	2.18	.750				2.50	8.01	15.5	20.5	18.0	14.0	9.01	5.81	3.00	1.70	1.00	.501	.250	.120
34	74.5	14.0	2.08	.466					2.73	7.27	15.2	19.7	18.2	14.6	13.1	6.06	3.33	1.82	1.01		

References to the Original Sources of Data Reproduced in Tabular Data (G-5.4 through G-5.11)

8. H. R. Andrews, E. Almqvist, C. Broude, M. A. Eswaran, J. A. Kuehner, and A. E. Litherland, The Tandem Quarterly (published by High Voltage Engineering Corp., Burlington, Mass.), 1, 1 (1963).

14. H. F. Batho, Phys. Rev. 42, 753 (1932).

29. S. Datz, H. O. Lutz, L. B. Bridwell, C. D. Moak, H. D. Betz, and L. D. Ellsworth, Phys. Rev. A 2, 430 (1970).

30. S. Datz, C. D. Moak, H. O. Lutz, L. C. Northcliffe, and L. B. Bridwell, Atomic Data 2, 273 (1971).

34. B. Franzke, N. Angert, A. Moller, and Ch. Schmelzer, Phys. Letts. 25 A, 769 (1967); B. Franzke (private communication).

35. B. Franzke, N. Angert, and Ch. Schmelzer, IEE-NS 19, (2), 266 (1972); B. Franzke (private communication).

37. L. Grodzins, R. Kalish, D. Murnick, R. J. v. de Graaff, F. Chmara, and P. H. Rose, Phys. Letts. 24 B, 282 (1967); F. M. Flasar, Mass. Inst. of Technology, 1967 (unpublished); L. Grodzins (private communication).

56. C. D. Moak, H. O. Lutz, L. B. Bridwell, L. C. Northcliffe, and S. Datz, Phys. Rev. 176, 427 (1968).

59. V. S. Nikolaev, I. S. Dmitriev, L. N. Fateeva, and Y. A. Teplova, Zh. Eksperim. i Teor. Fiz. 39, 905 (1960) [Sov. Phys. JETP 12, 627 (1961)].

65. L. I. Pivovar, V. M. Tubaev, and M. T. Nivikov, Zh. Eksperim. i Teor. Fiz. 48, 1022 (1965) [Sov. Phys. JEPT 21, 681 (1965)].

76. G. Ryding, A. B. Wittkower, and P. H. Rose, Phys. Rev. 184, 93 (1969).

77. G. Ryding, A. B. Wittkower, and P. H. Rose, Phys. Rev. 185, 129 (1969).

81. G. Ryding, A. B. Wittkower, and P. H. Rose, Phys. Rev. A 3, 1958 (1971).

92. A. B. Wittkower and H. B. Gilbody, Proc. Phys. Soc. 90, 353 (1967).

94. A. B. Wittkower and G. Ryding, Phys. Rev. A 4, 226 (1971).

H. PARTICLE AND PHOTON INTERACTIONS WITH SOLIDS

The data presented in Chapter H (pages 827 - 892) of Vol. II are sufficient for our present purpose; hence, no additional data appear here. The reader, however, may be interested in the recent references listed below.

General References

L. Fiermans, J. Vennik, and W. Dekeyser (Eds.), "Electron and Ion Spectroscopy of Solids" (NATO Advanced Study Institutes Series. Series B: Physics 32), Plenum Press, New York (1978).

F. O. Goodman and H. Y. Wachman, "Dynamics of Gas-Surface Scattering", Academic Press, New York (1976).

L. Marton (Ed.), "Advances in Electronics and Electron Physics 44, Academic Press, New York (1977).

N. H. Tolk, J. C. Tully, W. Heiland, and C. W. White (Eds.), "Inelastic Ion-Surface Collisions", Academic Press, New York (1977).

I. SECONDARY ELECTRON SPECTRA

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General References

G. N. Ogurtsov, "Energy Spectra of Electrons Ejected in Ion-Atom Collisions," Rev. Mod. Phys. 44, 1 (1972).

N. Stolterfoht, "Excitation in Energetic Ion-Atom Collisions Accompanied by Electron Emission," in Topics in Current Physics, V.5, I. A. Sellin (Ed.) (Springer-Verlag, Berlin, 1978), 155-199.

M. E. Rudd and J. H. Macek, "Mechanisms of Electron Production in Ion-Atom Collisions," in Case Studies in Atomic Physics, V.3, E. W. McDaniel and M. R. C. McDowell (Eds.) (North-Holland, Amsterdam, 1972) 47-136.

M. E. Rudd, L. H. Toburen, and N. Stolterfoht, "Differential Cross Sections for Ejection of Electrons from Helium by Protons," Atomic Data and Nuclear Data Tables 18, 413 (1976).

C. B. Opal, E. C. Beaty, and W. K. Peterson, "Tables of Secondary Electron Production Cross Sections," Atomic Data 4, 209 (1973).

E. C. Beaty, "Measurements of Energy and Angular Distribution of Secondary Electrons," Radiation Research 64, 70 (1975).

N. Oda, "Energy and Angular Distributions of Electrons from Atoms and Molecules by Electron Impact," Radiation Research 64, 96 (1975).

M. E. Rudd, "Mechanisms of Electron Production in Ion-Atom Collisions," Radiation Research 64, 153 (1975).

Y.-K. Kim, "Energy Distribution of Secondary Electrons. I. Consistency of Experimental Data," Radiation Research 61, 21 (1975).

Y.-K. Kim, "Energy Distribution of Secondary Electrons. II. Normalization and Extrapolation of Experimental Data," Radiation Research 64, 205 (1975).

General Comments

The energy distributions of secondary electrons in this chapter are all given as absolute cross sections. Since these electrons form a continuum, the cross sections are differential in the secondary electron energy. They are, thus, generally referred to as singly differential cross sections (SDCS) and written $d\sigma/d\varepsilon$ where ε is the secondary electron energy, or $d\sigma/dE$ where E is the energy transfer, the sum of ε and the first ionization potential of the atom or molecule.

These energies are often taken to be in units of Rydbergs (13.605 eV) and written E/R or σ/R; sometimes plots are made versus the inverse of the energy in Rydbergs, given by R/E.

Recent theoretical work has shown that $d\sigma/dE$ divided by the Rutherford cross section for the same energy transfer E gives a particularly simple curve [Y.- K. Kim, Radiant. Res. 61, 21 (1975); ibid 64, 205 (1975); L.H. Toburen, S.T. Manson, and Y.- K. Kim, Phys. Rev. A 17, 148 (1978]. This ratio is generally denoted by the symbol Y(E,T) [T is the incident kinetic energy] or simply Y(E). The plots of Y(E,T) closely mirror the optical (photoionization) transitions for small E and for large E are roughly constant and equal to the number of bound electrons in the ionization.

Accuracy of the Data

In general the accuracy of the data presented in this chapter is $\pm$ 20% absolute and $\pm$ 10% relative. In various places in the chapter data taken by more than one group, for the same collision, are given and the comparison of these data suggests that the above error limits are much larger than the differences in the data among various laboratories.

One caveat should be mentioned, however. The data for low energy secondary electrons, below about 10 eV, are not as good as the higher energy data owing to transmission difficulties for low energy electrons with electrostatic analyzers. This does not apply to time-of-flight electron energy analysis and such data should be good down to 1 eV. Such data are noted.

Comments Concerning Clusters

In dealing with a system which is at a pressure of 0.1 atm or greater, the effects of cluster formation in the target gas must be considered. A study of this effect on the secondary electron spectrum for electron impact ionization of H_2O has been carried out [R. F. Mathis and D. A. Vroom, J. Chem. Phys. 64, 1146 (1976)]. The secondary electrons were collected only at 90° and a detectable drop was found in the number of low energy secondary electrons, despite the fact that analysis showed only 1.8% of the H_2O molecules were in clusters.

Thus, the conclusion from this study is that clustering can be of significance in altering the secondary electron spectrum. Unfortunately, no other data are available to check this result.

I-1. ENERGY SPECTRA OF SECONDARY ELECTRONS FROM ELECTRON IMPACT IONIZATION

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Tabular Data I-1.A-1. Single differential cross sections (secondary electron spectra) for $e^- + He$ collisions (units of 10^{-20} cm^2/eV).

Primary Electron Energy

SECONDARY ENERGY (EV)	50 EV	100 EV	200 EV	300 EV	500 EV	1000 EV	2000 EV
4.13	153.	192.	194.	155.	112.	45.4	26.9
4.32	152.	187.	189.	149.	110.	45.1	26.5
4.53	152.	184.	192.	146.	109.	45.0	26.6
4.74	149.	164.	184.	147.	106.	45.5	26.3
4.97	147.	181.	183.	141.	103.	44.0	25.5
5.21	145.	180.	182.	140.	101.	43.3	25.3
5.45	146.	175.	181.	138.	99.	42.6	25.4
5.71	144.	174.	179.	135.	98.	42.2	24.4
5.59	145.	174.	171.	134.	96.	41.4	24.3
6.27	143.	165.	167.	131.	92.	40.6	23.7
6.57	141.	161.	166.	129.	92.	40.8	23.2
6.88	133.	154.	157.	123.	88.	38.9	23.1
7.21	128.	148.	152.	122.	87.	39.1	22.7
7.6	123.	143.	146.	118.	83.	37.2	21.8
7.9	119.	140.	145.	115.	82.	37.1	21.4
8.3	116.	134.	140.	113.	80.	36.1	20.9
8.7	115.	131.	135.	108.	78.	35.4	20.3
9.1	110.	125.	130.	106.	75.	34.2	19.8
9.5	108.	121.	127.	101.	72.1	33.3	19.1
10.0	106.	118.	125.	98.	70.1	32.1	18.6
10.5	102.	113.	120.	96.	67.6	31.3	18.3
11.0	100.	107.	115.	91.	65.6	30.4	17.6
11.5	98.	104.	109.	89.	62.5	29.7	17.0
12.0	96.	99.	108.	85.	60.7	28.6	16.8
12.6	95.	95.	102.	82.	58.6	27.5	15.8
13.2	93.	92.	98.	80.	56.4	26.2	15.5
13.8	89.	88.	95.	77.	54.4	25.9	14.7
14.5	90.	84.	90.	72.4	51.3	24.6	14.0
15.2	88.	81.	87.	70.2	50.2	23.2	13.7
15.9	87.	78.	81.	65.8	46.5	22.2	13.0
16.7	87.	76.	76.	64.0	45.1	21.3	12.6
17.4	85.	71.6	73.3	61.6	43.3	20.5	11.9
18.3	86.	68.2	71.0	58.3	40.3	19.7	11.5
19.1	86.	64.2	65.0	54.0	38.8	19.0	10.7
20.1	86.	61.5	63.4	51.6	36.1	17.9	10.3
21.0	86.	58.4	58.8	48.7	35.0	16.8	9.9
22.0	86.	56.1	57.0	45.9	32.9	16.1	9.3
23.1	86.	54.1	52.5	44.1	31.2	15.4	9.0
24.2	84.	51.5	49.4	41.1	29.5	14.4	8.4
25.3		49.5	46.8	38.6	27.7	13.6	[illegible].9
26.5		47.1	44.2	36.5	26.1	12.9	7.41
27.8		45.4	41.2	34.0	24.1	12.2	6.95
29.1		42.9	38.0	31.5	22.8	11.5	6.58
30.5		41.0	35.5	30.6	21.4	10.8	6.36
31.9		39.5	35.0	28.4	20.5	10.4	6.07
33.5		38.7	32.6	27.1	19.6	10.0	5.72
35.1		38.4	29.4	24.5	18.4	9.1	5.32
36.7		37.2	27.1	22.1	16.4	8.1	4.67
38.5		35.5	24.5	20.6	15.1	7.6	4.36
40.3		35.1	20.9	18.0	13.5	6.64	4.00
42.2		34.2	19.8	16.0	12.1	6.04	3.61
44.2		33.3	17.8	14.9	11.1	5.70	3.30
46.3		33.3	16.5	13.9	10.2	5.30	3.04
48.5		33.2	15.3	12.7	9.3	4.79	2.80
50.9			13.8	11.3	8.5	4.43	2.53
53.3			12.9	10.5	7.8	4.01	2.37
55.8			12.1	9.6	7.15	3.60	2.18
58.5			11.0	8.5	6.65	3.42	1.99
61.3			9.6	7.9	5.91	3.11	1.79
64.2			9.3	6.99	5.43	2.81	1.66
67.2			8.6	6.47	4.87	2.59	1.56
70.4			8.2	5.99	4.47	2.33	1.38
73.8			7.6	5.36	4.22	2.16	1.25
77.			7.07	4.79	3.78	1.94	1.20
81.			6.59	4.39	3.39	1.80	1.07
85.			6.37	4.12	2.99	1.63	.98
89.			6.31	3.69	2.76	1.46	.83
93.			6.12	3.37	2.51	1.33	.76
98.			6.29	3.01	2.23	1.16	.711
102.				2.75	2.09	1.09	.679

Tabular Data I-1.A-1. Single differential cross sections (secondary electron spectra for $e^- + He$ collision (units of 10^{-20} cm^2/eV)
(continued)

Primary Electron Energy

SECONDARY ENERGY (EV)	300 EV	500 EV	1000 EV	2000 EV
107.	2.44	1.84	.99	.625
112.	2.36	1.68	.91	.542
117.	2.26	1.55	.81	.489
123.	2.06	1.37	.731	.435
129.	1.89	1.25	.664	.395
135.	1.84	1.14	.579	.363
141.	1.76	1.02	.538	.327
148.	1.73	.92	.488	.305
155.		.82	.433	.263
163.		.76	.392	.245
170.		.712	.355	.223
179.		.616	.319	.193
187.		.586	.286	.179
196.		.546	.250	.156
205.		.533	.233	.146

Reference: These data were taken from C. B. Opal, E. C. Beaty, and W. K. Peterson, Atomic Data 4, 209 (1972).

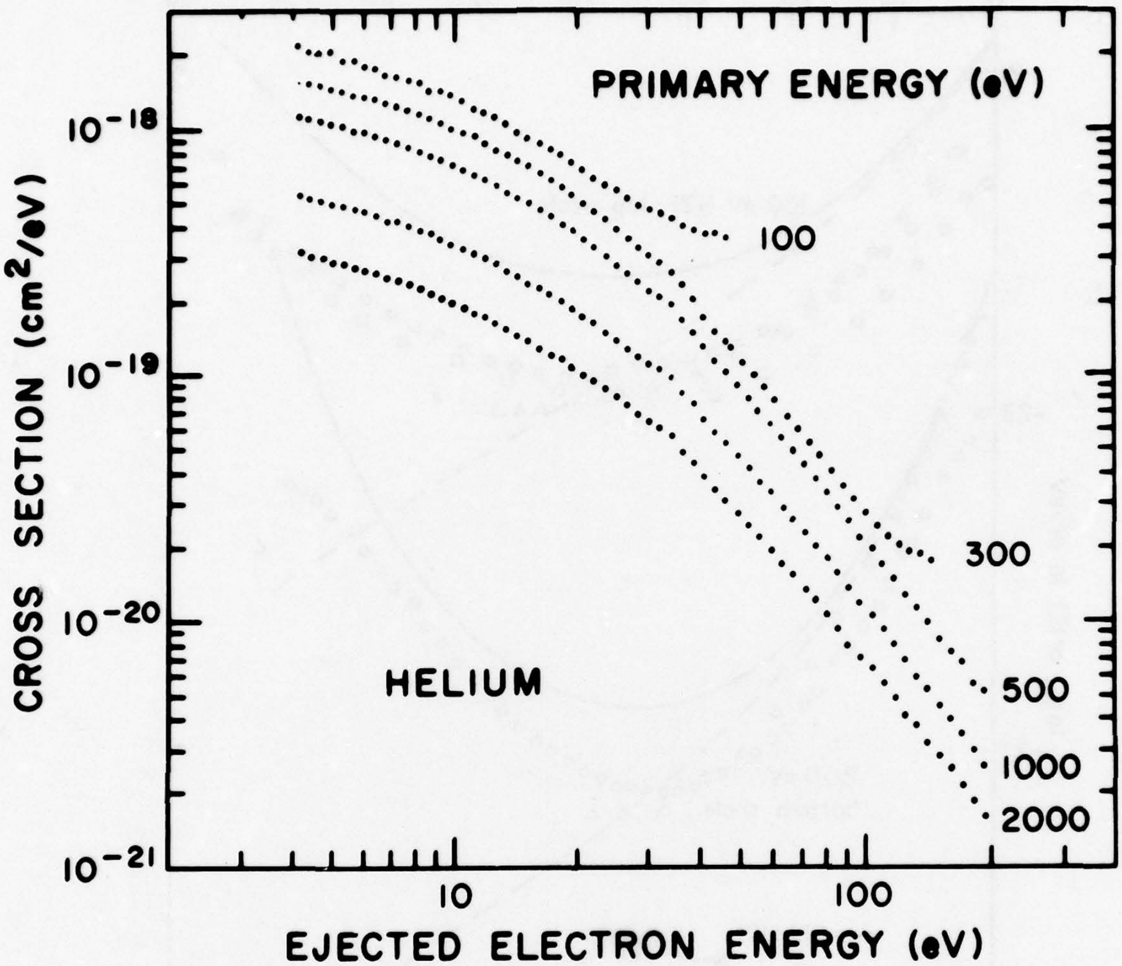
Tabular Data I-1.A-2. Single differential cross sections (secondary electron spectra) for e^- + He collisions (units of m^2/eV).

ES EV	EP = 100. EV	EP = 200. EV
4.0	1.835-22	9.280-23
5.0	1.651-22	8.695-23
6.0	1.469-22	8.327-23
7.0	1.299-22	7.819-23
8.0	1.161-22	7.381-23
9.0	1.069-22	7.191-23
10.0	1.002-22	6.915-23
12.0	9.027-23	6.578-23
14.0	8.010-23	5.774-23
16.0	7.053-23	5.225-23
18.0	6.396-23	4.799-23
20.0	5.748-23	4.054-23
22.0	5.703-23	3.821-23
24.0	5.369-23	3.291-23
26.0	4.987-23	3.038-23
28.0	4.782-23	2.723-23
30.0	4.672-23	2.543-23
35.0	4.323-23	2.016-23
40.0	4.080-23	1.756-23
45.0	4.273-23	1.383-23
50.0	4.702-23	1.177-23
55.0	5.600-23	1.061-23
60.0	6.605-23	9.393-24
65.0	8.241-23	8.554-24
70.0	1.069-22	8.294-24
[illegible].0	1.381-22	7.650-24

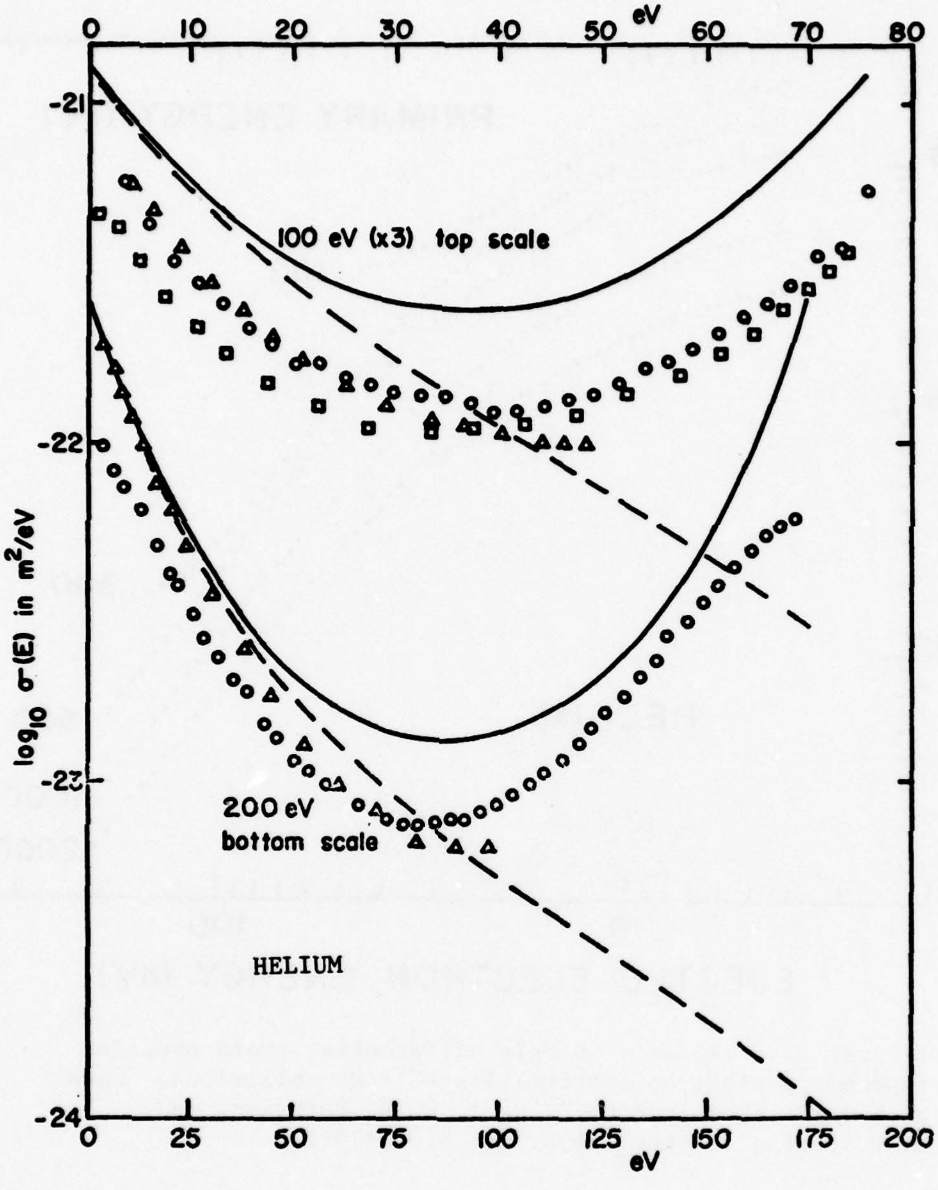
ES EV	EP = 200. EV
80.0	7.427-24
85.0	7.436-24
90.0	7.695-24
95.0	7.903-24
100.0	8.523-24
110.0	1.025-23
120.0	1.372-23
130.0	1.782-23
140.0	2.446-23
150.0	3.431-23
160.0	4.584-23
170.0	5.815-23

Note: ES is ejected electron energy in eV and EP is primary electron energy.

Reference: These data were taken from M. E. Rudd and R. D. DuBois, Phys. Rev. A 16, 26 (1977).



Graphical Data I-1.A-3. Single differential cross sections (secondary electron spectra) for e^- + He collisions. These data were taken from C. B. Opal, W. K. Peterson, and E. C. Beaty, J. Chem. Phys. 55, 4100 (1971).



Graphical Data I-1.A-4. Single differential cross sections (secondary electron spectra) for e^- + He collisions. These data were taken from M. E. Rudd and R. D. Dubois, Phys. Rev. A 16, 26 (1977); the original data were from: o - previous reference; Δ - C. B. Opal, E. C. Beaty, and W. K. Peterson, Atomic Data 4, 209 (1972); □ - M. Goodrich, Phys. Rev. 52, 259 (1937); -- and — unpublished theoretical calculations of S. T. Manson including only secondary and secondary plus scattered electrons, respectively.

Tabular Data I-1.A-5. Single differential cross sections (secondary electron spectra) for e^- + Ne collisions (units of 10^{-20} cm^2/eV).

Primary Electron Energy = 500 eV

SECONDARY ENERGY (EV)	Ne	SECONDARY ENERGY (EV)	Ne
4.13	158.	42.2	36.3
4.32	156.	44.2	34.4
4.53	153.	46.3	31.6
4.74	153.	48.5	29.8
4.97	154.	50.9	27.0
5.21	151.	53.3	25.4
5.45	147.	55.8	23.5
5.71	144.	58.5	21.6
5.99	144.	61.3	20.0
6.27	144.	64.2	18.3
6.57	140.	67.2	16.7
6.88	138.	70.4	15.1
7.21	135.	73.8	13.9
7.6	135.	77.	12.8
7.9	133.	81.	11.4
8.3	133.	85.	10.5
8.7	130.	89.	9.4
9.1	128.	93.	8.5
9.5	123.	98.	7.7
10.0	124.	102.	6.85
10.5	119.	107.	6.08
11.0	117.	112.	5.55
11.5	115.	117.	5.02
12.0	115.	123.	4.45
12.6	112.	129.	4.03
13.2	108.	135.	3.69
13.8	102.	141.	3.25
14.5	101.	148.	2.90
15.2	98.	155.	2.67
15.9	96.	163.	2.37
16.7	93.	170.	2.17
17.4	90.	179.	1.99
18.3	88.	187.	1.81
19.1	84.	196.	1.69
20.1	83.	205.	1.60
21.0	83.		
22.0	79.		
23.1	74.9		
24.2	71.9		
25.3	67.5		
26.5	64.1		
27.8	61.0		
29.1	57.9		
30.5	54.4		
31.9	52.3		
33.5	49.1		
35.1	46.3		
36.7	44.2		
38.5	41.6		
40.3	38.6		

Reference: These data were taken from C. B. Opal, E. C. Beaty, and W. K. Peterson, Atomic Data 4, 209 (1972).

Tabular Data I-1.A-6. Single differential cross sections (secondary electron spectra) for $e^- + Ne$ collisions (units of m^2/eV).

ES EV	EP = 100. EV	EP = 250. EV	EP = 500. EV
4.0	2.400-21		7.390-20
5.0	1.994-21	8.629-23	8.141-20
6.0	2.021-21	8.844-23	8.891-20
7.0	1.918-21	9.060-23	9.578-20
8.0	1.858-21	9.275-23	9.593-20
9.0	1.811-21	9.492-23	9.330-20
10.0	1.743-21	9.765-23	8.841-20
12.0	1.615-21	1.004-22	7.727-20
14.0	1.519-21	9.762-23	6.512-20
16.0	1.353-21	9.238-23	5.850-20
18.0	1.286-21	8.867-23	5.500-20
20.0	1.208-21	8.505-23	5.217-20
22.0	1.191-21	8.196-23	4.983-20
24.0	1.138-21	7.796-23	4.726-20
26.0	1.063-21	7.307-23	4.456-20
28.0	1.001-21	6.795-23	4.212-20
30.0	9.642-22	6.314-23	3.986-20
35.0	8.958-22	5.363-23	3.475-20
40.0	8.517-22	4.624-23	3.059-20
45.0	8.364-22	4.030-23	2.620-20
50.0	8.769-22	3.478-23	2.275-20
55.0	8.913-22	3.117-23	2.031-20
60.0	9.593-22	2.739-23	1.782-20
65.0	1.108-21	2.449-23	1.586-20
70.0	1.275-21	2.328-23	1.401-20
75.0	1.409-21	2.067-23	1.233-20
80.0		1.910-23	1.131-20
85.0		1.835-23	1.005-20

ES EV	EP = 250. EV	EP = 500. EV
90.0	1.696-23	9.344-21
95.0	1.513-23	8.155-21
100.0	1.486-23	7.631-21
110.0	1.457-23	6.159-21
120.0	1.469-23	5.198-21
130.0	1.536-23	4.472-21
140.0	1.738-23	3.953-21
150.0	1.944-23	3.542-21
160.0	2.232-23	3.110-21
170.0	2.573-23	2.948-21
180.0	2.995-23	2.617-21
190.0	3.427-23	2.269-21
200.0	3.908-23	2.226-21
220.0	4.331-23	2.097-21
240.0		2.120-21
260.0		2.286-21
280.0		2.742-21
300.0		3.197-21
320.0		3.929-21
340.0		4.933-21
360.0		6.481-21
380.0		8.340-21
400.0		1.098-20
420.0		1.342-20
440.0		1.471-20
460.0		1.228-20
480.0		8.835-21

Note: ES is ejected electron energy in eV and EP is primary electron energy.

Reference: These data were taken from R. D. DuBois and M. E. Rudd, Phys. Rev. A 17, 843 (1978).

Tabular Data I-1.A-7. Single differential cross sections (secondary electron spectra) for $e^- + Ar$ collisions (units of 10^{-20} cm^2/eV).

Primary Electron Energy = 500 eV

SECONDARY ENERGY (EV)	Ar
4.13	890.
4.32	880.
4.53	870.
4.74	850.
4.97	840.
5.21	810.
5.45	810.
5.71	800.
5.99	790.
6.27	750.
6.57	750.
6.88	734.
7.21	716.
7.6	692.
7.9	676.
8.3	656.
8.7	648.
9.1	641.
9.5	600.
10.0	544.
10.5	520.
11.0	531.
11.5	499.
12.0	473.
12.6	435.
13.2	402.
13.8	364.
14.5	336.
15.2	308.
15.9	281.
16.7	251.
17.4	216.
18.3	193.
19.1	164.
20.1	145.
21.0	125.
22.0	108.
23.1	93.
24.2	82.
25.3	72.0
26.5	64.3
27.8	56.5
29.1	51.4
30.5	47.0
31.9	42.2
33.5	38.7
35.1	36.0
36.7	34.0
38.5	31.8
40.3	29.8

SECONDARY ENERGY (EV)	Ar
42.2	28.6
44.2	27.4
46.3	25.7
48.5	24.4
50.9	23.1
53.3	21.8
55.8	19.9
58.5	19.0
61.3	17.8
64.2	16.4
67.2	15.2
70.4	14.1
73.8	13.0
77.	11.7
81.	10.8
85.	9.7
89.	9.2
93.	8.3
98.	7.5
102.	6.97
107.	6.47
112.	5.74
117.	5.29
123.	5.03
129.	4.52
135.	4.20
141.	4.02
148.	3.82
155.	3.79
163.	3.81
170.	4.01
179.	4.54
187.	5.54
196.	5.20
205.	3.04

Reference: These data were taken from C.B. Opal, E.C. Beaty, and W.K. Peterson, Atomic Data 4, 209 (1972).

Tabular Data I-1.A-8. Single differential cross sections (secondary electron spectra) for $e^- + Ar$ collisions (units of m^2/eV).

ES EV	EP = 100. EV	250. EV	500. EV
4.0	2.154-21	1.833-21	1.179-21
5.0	1.748-21	1.359-21	9.471-22
6.0	1.571-21	1.195-21	8.920-22
7.0	1.450-21	1.090-21	8.379-22
8.0	1.372-21	1.019-21	7.717-22
9.0	1.296-21	9.515-22	6.954-22
10.0	1.199-21	8.664-22	6.166-22
12.0	1.026-21	7.166-22	4.925-22
14.0	8.311-22	5.596-22	3.758-22
16.0	6.452-22	4.212-22	2.786-22
18.0	4.770-22	3.029-22	1.986-22
20.0	3.703-22	2.248-22	1.481-22
22.0	3.042-22	1.727-22	1.152-22
24.0	2.610-22	1.351-22	9.176-23
26.0	2.292-22	1.093-22	7.571-23
28.0	2.065-22	9.151-23	6.460-23
30.0	1.917-22	7.883-23	5.650-23
35.0	1.738-22	6.047-23	4.505-23
40.0	1.708-22	5.068-23	3.830-23
45.0	1.850-22	4.341-23	3.227-23
50.0	2.126-22	3.836-23	2.791-23
55.0	2.439-22	3.456-23	2.505-23
60.0	2.999-22	3.140-23	2.243-23
65.0	4.036-22	2.851-23	1.989-23
70.0	5.136-22	2.606-23	1.759-23
75.0	5.766-22	2.409-23	1.558-23
80.0	6.320-22	2.234-23	1.392-23

ES EV	EP = 250. EV	500. EV
85.0	2.088-23	1.250-23
90.0	1.923-23	1.125-23
95.0	1.704-23	1.021-23
100.0	1.585-23	9.341-24
110.0	1.555-23	7.880-24
120.0	1.676-23	7.001-24
130.0	1.849-23	6.578-24
140.0	2.145-23	6.328-24
150.0	2.517-23	6.034-24
160.0	3.094-23	5.868-24
170.0	3.863-23	5.857-24
180.0	5.111-23	5.851-24
190.0	6.876-23	6.006-24
200.0	1.018-22	5.509-24
220.0	2.477-22	3.443-24
240.0		3.287-24
260.0		2.732-24
280.0		2.726-24
300.0		3.409-24
320.0		4.245-24
340.0		5.384-24
360.0		6.925-24
380.0		9.274-24
400.0		1.325-23
420.0		2.027-23
440.0		3.549-23
460.0		7.122-23
480.0		8.160-23

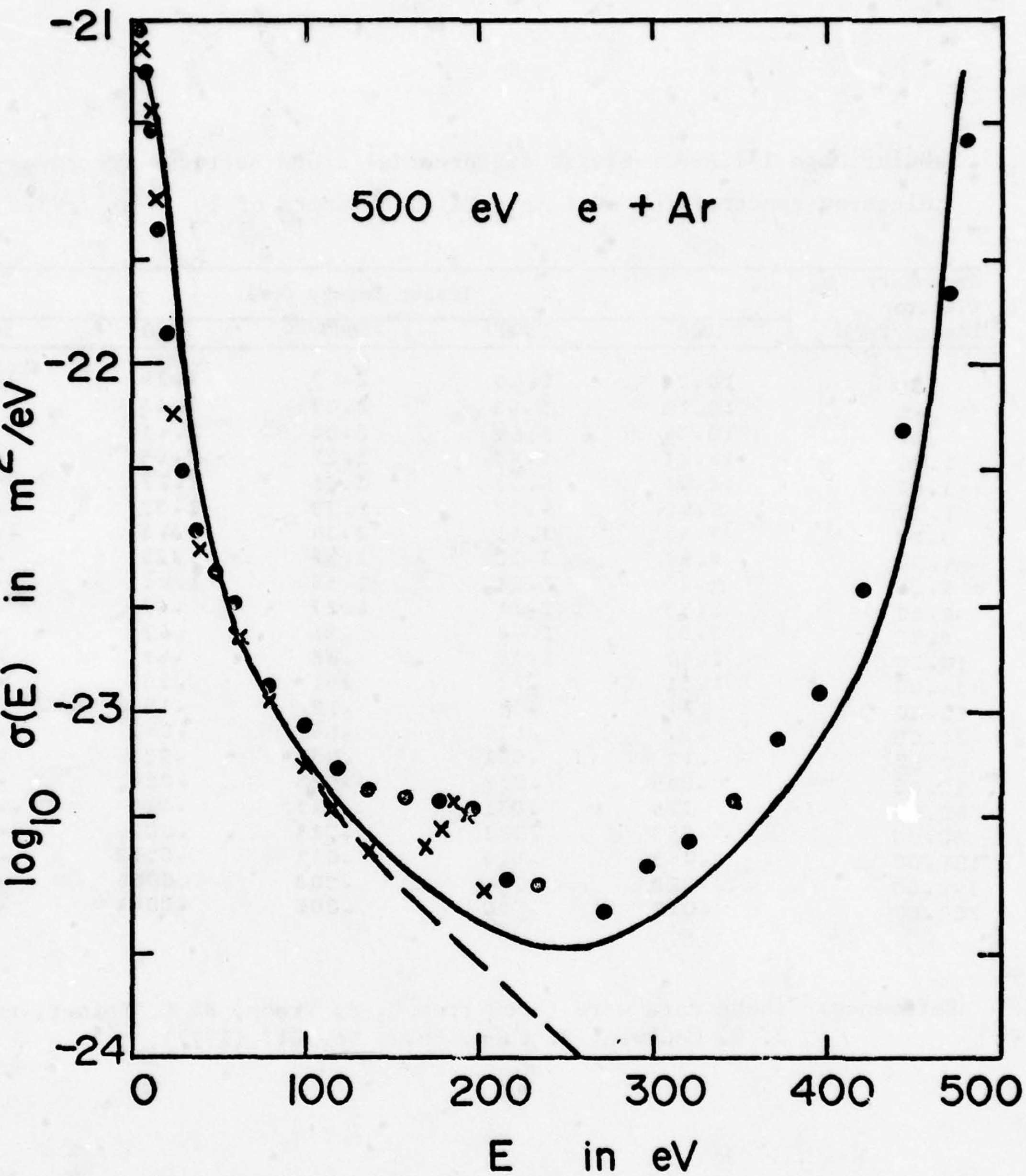
Note: ES is ejected electron energy in eV and EP is primary electron energy.

Reference: These data were taken from M. E. Rudd and R. D. DuBois, Phys. Rev. A <u>16</u>, 26 (1977).

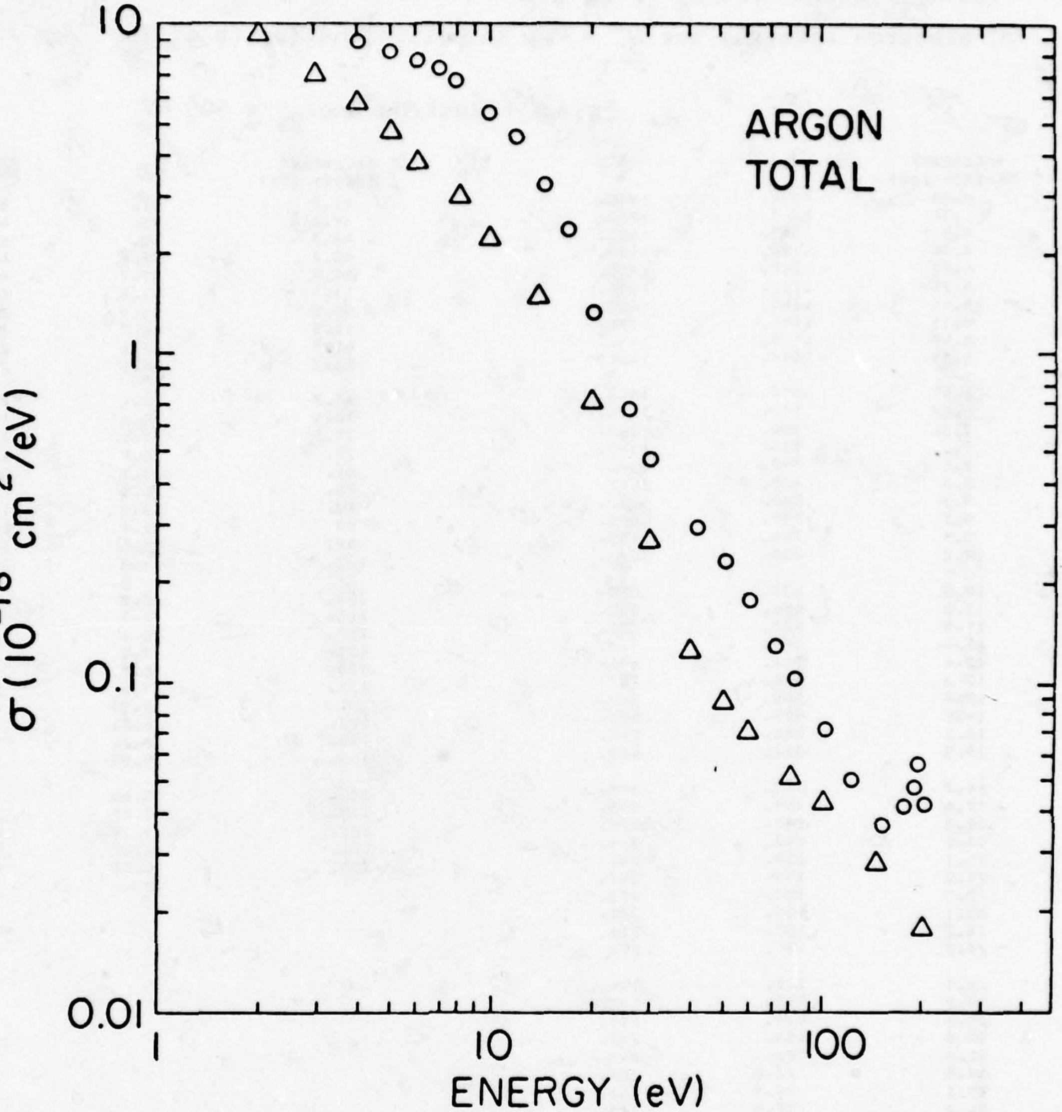
Tabular Data I-1.A-9. Single differential cross sections (secondary electron spectra) for $e^- + Ar$ collision (units of 10^{-18} cm^2/eV).

Secondary Electron Energy (eV)	Impact Energy (eV)				
	1000	2500	5000	7500	10000
.50	10.29	5.49	2.42	1.94	1.51
.60	10.75	5.49	2.47	2.15	1.53
.80	10.54	5.81	3.05	2.41	1.77
1.00	11.21	5.43	3.27	2.09	1.86
1.40	11.21	5.13	3.31	2.27	1.79
2.00	9.66	4.97	2.79	1.32	1.55
3.00	7.41	3.81	2.34	1.63	1.25
4.50	5.87	3.10	1.92	1.23	.94
5.00	4.30	2.59	1.55	1.03	.75
6.00	3.93	2.11	1.27	.87	.65
8.00	3.92	1.48	.91	.62	.50
10.00	2.47	1.16	.88	.49	.39
14.00	1.51	.73	.41	.30	.23
20.00	.71	.34	.19	.15	.11
30.00	.27	.11	.067	.047	.035
40.00	.12	.061	.036	.023	.019
50.00	.089	.039	.025	.014	.014
60.00	.075	.031	.019	.010	.011
80.00	.053	.023	.014	.0076	.0086
100.00	.043	.018	.011	.0072	.0068
140.00	.029	.014	.009	.0058	.0057
200.00	.018	.010	.005	.0044	.0043

Reference: These data were taken from D. A. Vroom, R. L. Palmer, and J. W. McGowan, J. Chem. Phys. 66, 647 (1977).



Graphical Data I-1.A-9. Single differential cross sections (secondary electron spectra) for e^- + Ar collisions. These data were taken from R. D. Dubois and M. E. Rudd, Phys. Rev. A 17, 843 (1978); the original data were from: • - previous reference; x - C. B. Opal, E. C. Beaty, and W. K. Peterson, Atomic Data 4, 209 (1972); -- and —, unpublished theoretical calculations of S. T. Manson including only secondary and secondary plus scattered electrons, respectively.



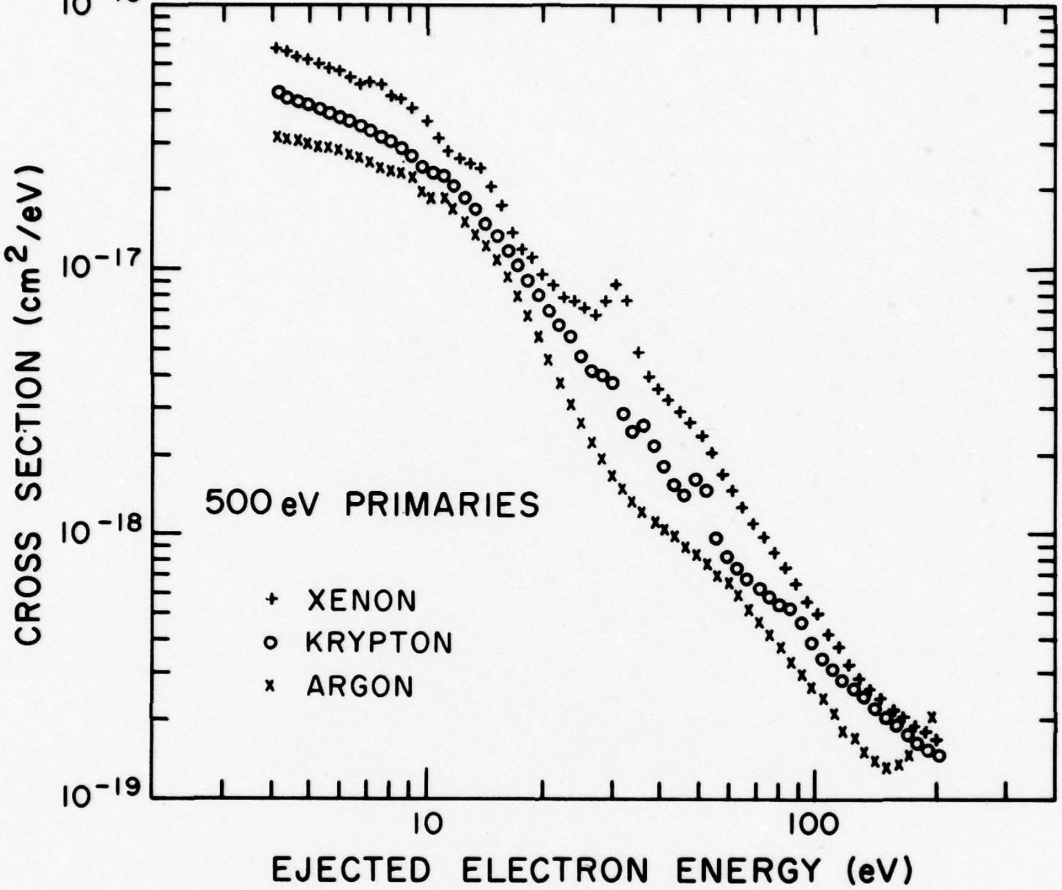
Graphical Data I-1.A.10. Single differential cross sections (secondary electron spectra) for e^- + Ar collisions for 500 eV (o) and 1000 eV (Δ). These data were taken from D. A. Vroom, R. L. Palmer, and J. W. McGowan, J. Chem. Phys. 66, 647 (1977); the 1000 eV data are from the previous reference and the 500 eV data are from C. B. Opal, E. C. Beaty and W. K. Peterson, Atomic Data 4, 209 (1972).

Tabular Data I-1.A-11. Single differential cross sections (secondary electron spectra) for $e^- + Kr$, Xe collisions (units of $10^{-20}\ cm^2/eV$).

Primary Electron Energy = 500 eV

SECONDARY ENERGY (EV)	Kr	Xe
4.13	1330.	1900.
4.32	1280.	1850.
4.53	1260.	1800.
4.74	1220.	1750.
4.97	1210.	1710.
5.21	1180.	1690.
5.45	1140.	1650.
5.71	1100.	1570.
5.99	1090.	1550.
6.27	1050.	1480.
6.57	1030.	1440.
6.88	980.	1370.
7.21	950.	1380.
7.6	920.	1380.
7.9	890.	1340.
8.3	860.	1220.
8.7	830.	1230.
9.1	790.	1170.
9.5	744.	1130.
10.0	700.	1070.
10.5	671.	950.
11.0	666.	850.
11.5	622.	780.
12.0	589.	729.
12.6	541.	696.
13.2	506.	702.
13.8	464.	682.
14.5	419.	581.
15.2	386.	540.
15.9	352.	468.
16.7	322.	395.
17.4	293.	346.
18.3	268.	325.
19.1	242.	306.
20.1	219.	267.
21.0	199.	258.
22.0	180.	233.
23.1	169.	221.
24.2	152.	211.
25.3	134.	208.
26.5	122.	194.
27.8	115.	191.
29.1	115.	211.
30.5	107.	232.
31.9	86.	243.
33.5	73.0	207.
35.1	74.9	146.
36.7	75.5	116.
38.5	65.6	106.
40.3	56.8	98.
42.2	91.	50.0
44.2	83.	44.6
46.3	80.	40.8
48.5	72.6	45.0
50.9	67.7	49.3
53.3	61.2	41.5
55.8	54.4	29.6
58.5	46.7	25.1
61.3	42.2	23.3
64.2	36.6	21.5
67.2	34.0	20.2
70.4	30.0	18.8
73.8	27.5	17.8
77.	25.0	17.0
81.	23.1	15.8
85.	20.9	15.4
89.	18.4	14.9
93.	16.4	13.2
98.	15.0	11.7
102.	13.8	10.4
107.	12.0	9.4
112.	11.3	8.9
117.	10.2	8.2
123.	9.0	7.6
129.	8.2	7.24
135.	7.6	6.94
141.	6.97	6.50
148.	6.61	6.11
155.	6.21	5.77
163.	5.59	5.48
170.	5.66	5.12
179.	5.07	4.84
187.	5.19	4.60
196.	4.69	4.43
205.	4.60	4.27

Reference: These data were taken from C. B. Opal, E. C. Beaty, and W. K. Peterson, Atomic Data 4, 209 (1972).



Graphical Data I-1.A-12. Single differential cross sections (secondary electron spectrum) for e^- + Ar, Kr, Xe collisions. These data were taken from C. B. Opal, W. K. Peterson, and E. C. Beaty, J. Chem. Phys. 55, 4100 (1971).

Section I-1.B. SECONDARY ELECTRON ENERGY SPECTRA FOR ELECTRON IMPACT IONIZATION OF THE MOLECULES H_2, O_2, N_2, CO_2, CO, NO, CH_4, H_2O, NH_3, and C_2H_2

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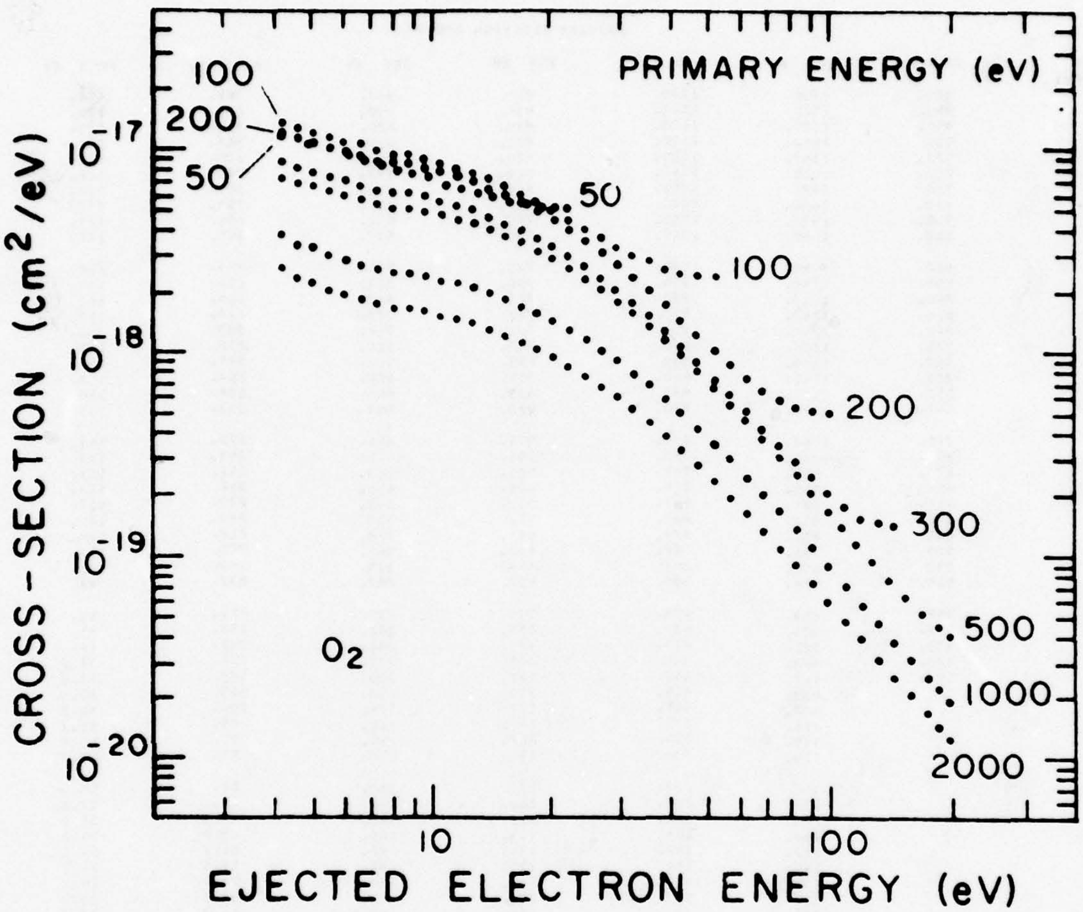
Tabular Data I-1.B-1. Single differential cross sections (secondary electron spectra) for $e^- + O_2$ collisions (units of 10^{-20} cm^2/eV).

SECONDARY ENERGY (EV)	PRIMARY ELECTRON ENERGY = 50 EV	100 EV	200 EV	300 EV	500 EV	1000 EV	2000 EV
4.13	1250.	1420.	1250.	910.	760.	339.	230.
4.32	1210.	1360.	1170.	860.	724.	316.	213.
4.53	1170.	1330.	1150.	820.	703.	307.	210.
4.74	1100.	1290.	1130.	810.	680.	301.	205.
4.97	1080.	1260.	1110.	790.	678.	297.	202.
5.21	1060.	1220.	1070.	770.	650.	289.	193.
5.45	1020.	1190.	1050.	749.	640.	279.	188.
5.71	1010.	1140.	1020.	725.	620.	270.	184.
5.59	970.	1130.	1010.	731.	615.	267.	179.
6.27	930.	1110.	970.	702.	600.	265.	179.
6.57	930.	1090.	960.	690.	589.	261.	173.
6.88	900.	1060.	920.	667.	569.	253.	169.
7.21	860.	1020.	890.	654.	553.	247.	165.
7.6	830.	1000.	870.	627.	538.	240.	161.
7.9	810.	980.	870.	634.	528.	237.	156.
8.3	800.	970.	870.	624.	531.	236.	159.
8.7	760.	970.	870.	628.	526.	238.	157.
9.1	760.	960.	850.	619.	519.	238.	159.
9.5	760.	930.	810.	604.	509.	232.	155.
10.0	740.	890.	790.	584.	495.	230.	151.
10.5	700.	890.	790.	569.	485.	225.	149.
11.0	688.	870.	760.	557.	475.	223.	147.
11.5	674.	830.	750.	545.	466.	218.	144.
12.0	652.	810.	741.	532.	456.	215.	141.
12.6	638.	790.	719.	521.	442.	211.	140.
13.2	624.	780.	710.	511.	431.	204.	136.
13.8	605.	747.	657.	493.	420.	199.	132.
14.5	600.	711.	635.	468.	405.	190.	127.
15.2	586.	684.	615.	448.	386.	184.	123.
15.9	561.	650.	593.	437.	371.	178.	119.
16.7	560.	634.	565.	419.	362.	174.	115.
17.4	550.	604.	542.	404.	349.	168.	111.
18.3	536.	572.	521.	384.	329.	162.	108.
19.1	526.	552.	493.	364.	315.	155.	103.
20.1	516.	518.	473.	348.	301.	148.	97.
21.0	516.	494.	438.	332.	285.	138.	93.
22.0	523.	466.	416.	311.	272.	132.	88.
23.1	526.	446.	395.	296.	254.	126.	84.
24.2	532.	431.	377.	274.	240.	118.	79.
25.3		405.	344.	264.	227.	113.	74.6
26.5		389.	326.	243.	212.	106.	70.3
27.8		369.	298.	227.	195.	100.	66.6
29.1		348.	284.	213.	186.	95.	62.1
30.5		335.	261.	198.	174.	88.	58.1
31.9		318.	245.	187.	162.	81.	54.1
33.5		306.	228.	173.	152.	76.	50.6
35.1		292.	211.	159.	140.	71.9	47.3
36.7		278.	193.	146.	129.	65.9	44.1
38.5		270.	178.	133.	119.	60.6	40.1
40.3		261.	163.	124.	110.	56.2	37.2
42.2		253.	148.	112.	101.	51.2	34.2
44.2		250.	137.	102.	92.	47.6	31.4
46.3		249.	125.	93.	84.	43.6	28.7
48.5		246.	115.	86.	77.	39.7	26.2
50.9			105.	76.	69.4	36.6	24.0
53.3			99.	71.6	63.9	33.4	22.0
55.8			91.	65.4	58.1	30.7	20.1
58.5			83.	57.8	52.6	27.5	18.5
61.3			78.	54.2	47.7	25.0	16.9
64.2			72.8	48.8	42.6	22.7	15.1
67.2			68.5	44.1	38.9	20.5	13.8
70.4			63.1	40.3	35.3	18.9	12.6
73.8			60.1	36.3	31.7	16.6	11.1
77.			57.8	32.6	28.9	15.4	10.1
81.			55.8	30.3	25.7	13.6	9.3
85.			53.8	27.4	23.6	12.4	8.3
89.			52.1	25.6	20.9	11.3	7.5
93.			52.6	22.7	18.9	10.1	6.83
98.			51.6	21.3	16.7	9.1	5.98
102.				19.6	15.0	8.3	5.54

Tabular Data I-1.B-1. Single differential cross sections (secondary electron spectra) for $e^- + O_2$ collisions (units of 10^{-20} cm^2/eV) (continued)

SECONDARY ENERGY (EV)	PRIMARY ELECTRON ENERGY 300 EV	500 EV	1000 EV	2000 EV
107.	18.0	13.8	7.5	4.81
112.	17.1	12.7	6.63	4.43
117.	15.6	10.9	5.98	3.97
123.	15.2	10.1	5.40	3.60
129.	14.8	9.3	4.63	3.16
135.	14.3	8.1	4.40	2.87
141.	14.5	7.6	3.88	2.61
148.	14.3	6.80	3.52	2.33
155.		6.25	3.20	2.09
163.		5.52	2.92	1.87
170.		5.10	2.57	1.72
179.		4.69	2.34	1.55
187.		4.52	2.09	1.39
196.		4.09	1.91	1.25
205.		3.87	1.79	1.12

Reference: These data were taken from C.B. Opal, E.C. Beaty, and W.K. Peterson, Atomic Data 4, 209 (1972).



Graphical Data I-1.B-2. Single differential cross section (secondary electron spectrum) for $e^- + O_2$ collisions. These data were taken from E.C. Beaty, Radiation Research 64, 70 (1975).

Tabular Data I-1.B-3. Single differential cross sections (secondary electron spectra) for $e^- + N_2$ collisions (units of 10^{-20} cm^2/eV).

PRIMARY ELECTRON ENERGY =

SECONDARY ENERGY (EV)	50 EV	100 EV	200 EV	300 EV	500 EV	1000 EV	2000 EV
4.13	950.	1530.	1130.	850.	647.	301.	174.
4.32	950.	1510.	1120.	840.	640.	306.	176.
4.53	940.	1500.	1120.	830.	625.	311.	173.
4.74	930.	1480.	1100.	820.	616.	303.	171.
4.97	920.	1460.	1100.	820.	604.	300.	172.
5.21	910.	1500.	1090.	820.	597.	298.	172.
5.45	910.	1420.	1090.	810.	590.	301.	172.
5.71	890.	1440.	1070.	800.	592.	305.	172.
5.99	900.	1370.	1060.	790.	591.	306.	175.
6.27	880.	1420.	1040.	790.	577.	305.	170.
6.57	880.	1350.	1030.	780.	575.	303.	172.
6.88	850.	1290.	990.	750.	557.	295.	165.
7.21	840.	1310.	980.	729.	540.	288.	163.
7.6	820.	1260.	960.	722.	523.	279.	159.
7.9	810.	1240.	950.	721.	518.	283.	160.
8.3	790.	1200.	920.	708.	515.	278.	156.
8.7	780.	1180.	890.	683.	502.	275.	154.
9.1	770.	1140.	860.	661.	480.	264.	148.
9.5	750.	1100.	830.	639.	465.	258.	146.
10.0	743.	1090.	830.	676.	455.	256.	143.
10.5	715.	1060.	800.	609.	441.	250.	142.
11.0	696.	1010.	780.	598.	438.	248.	140.
11.5	673.	950.	748.	581.	423.	241.	138.
12.0	652.	910.	725.	566.	413.	242.	134.
12.6	639.	880.	692.	537.	393.	230.	129.
13.2	620.	850.	662.	514.	377.	222.	124.
13.8	601.	800.	623.	491.	358.	212.	118.
14.5	589.	736.	588.	462.	341.	203.	112.
15.2	573.	686.	547.	434.	319.	190.	105.
15.9	559.	638.	508.	402.	297.	177.	96.
16.7	549.	613.	476.	379.	277.	164.	91.
17.4	537.	566.	441.	353.	258.	153.	85.
18.3	534.	521.	410.	327.	241.	142.	78.
19.1	526.	488.	376.	302.	222.	134.	72.2
20.1	517.	447.	352.	280.	205.	122.	67.8
21.0		423.	319.	259.	189.	115.	62.5
22.0		389.	301.	239.	174.	106.	58.8
23.1		374.	275.	221.	162.	99.	53.7
24.2		350.	254.	207.	150.	91.	50.3
25.3		325.	238.	191.	139.	85.	47.7
26.5		308.	223.	179.	130.	81.	44.5
27.8		296.	204.	166.	121.	75.	41.6
29.1		285.	190.	155.	113.	71.4	39.0
30.5		260.	176.	143.	105.	65.6	36.2
31.9		252.	163.	134.	98.	61.7	34.1
33.5		246.	151.	123.	91.	57.9	31.2
35.1		236.	138.	113.	84.	53.4	29.2
36.7		227.	127.	104.	77.	48.8	26.7
38.5		225.	116.	95.	69.6	44.9	24.7
40.3		218.	106.	86.	64.6	41.1	22.8
42.2		214.	97.	79.	58.6	37.4	20.5
44.2		215.	88.	71.4	53.3	34.1	18.9
46.3		207.	81.	65.8	48.3	32.2	17.4
48.5		215.	72.8	59.8	44.3	28.7	15.8
50.9			68.0	53.7	40.1	26.1	14.4
53.3			62.8	49.7	36.6	23.7	13.1
55.8			57.1	45.0	33.5	21.5	12.1
58.5			52.7	40.5	30.0	19.5	11.0
61.3			48.7	36.6	27.4	18.3	10.1
64.2			45.1	33.7	24.7	16.6	9.2
67.2			43.0	30.5	22.5	14.7	8.3
70.4			39.9	27.6	20.3	13.8	7.5
73.8			38.1	25.2	18.5	12.3	6.87
77.			35.7	22.9	16.6	10.8	6.26
81.			34.9	20.8	15.2	10.2	5.65
85.			34.0	19.1	13.7	9.1	5.16
89.			33.0	17.5	12.5	8.2	4.69
93.			33.3	16.2	11.3	7.6	4.22
98.			33.3	14.6	10.2	6.92	3.79
102.				13.6	9.3	6.33	3.46

Tabular Data I-1.B-3. Single differential cross sections (secondary electron spectra) for $e^- + N_2$ collisions (units of 10^{-20} cm^2/eV) (continued)

	PRIMARY ELECTRON ENERGY =			
SECONDARY ENERGY (EV)	300 EV	500 EV	1000 EV	2000 EV
107.	12.5	8.3	5.64	3.13
112.	11.7	7.5	5.16	2.97
117.	10.8	6.97	4.74	2.66
123.	10.4	6.22	4.30	2.36
129.	9.8	5.70	3.83	2.14
135.	9.7	5.12	3.33	1.97
141.	9.4	4.58	3.01	1.80
148.	9.3	4.06	2.83	1.58
155.		3.68	2.48	1.44
163.		3.36	2.38	1.31
170.		3.06	2.06	1.19
179.		2.84	1.83	1.07
187.		2.59	1.67	.96
196.		2.46	1.51	.88
205.		2.33	1.44	.81

Reference: These data were taken from C.B. Opal, E.C. Beaty, and W.K. Peterson, Atomic Data 4, 209 (1972).

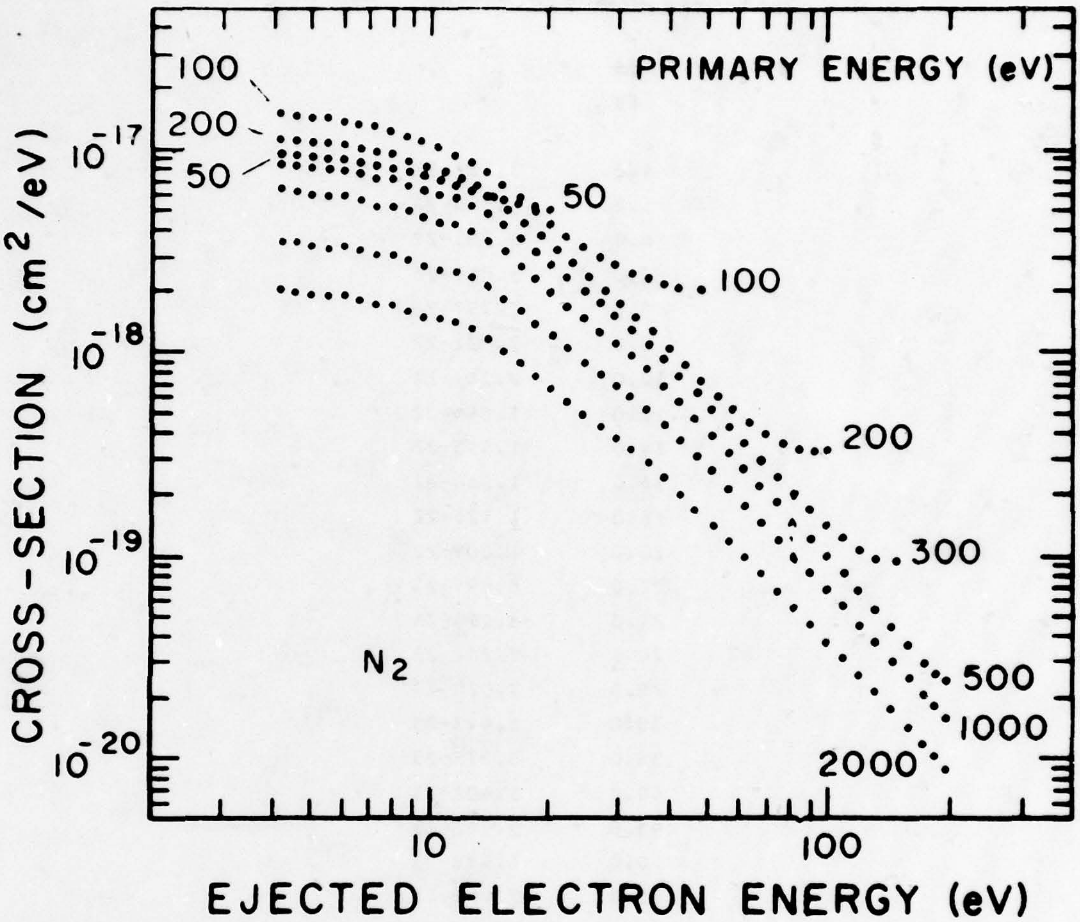
Tabular Data I-1.B-4. Single differential cross sections (secondary electron spectra) for $e^- + N_2$ collisions (units of m^2/eV).

ES EV	EP = 100. EV	EP = 250. EV	EP = 500. EV
4.0	1.710-21	9.428-22	4.828-22
5.0	1.560-21	7.746-22	4.639-22
6.0	1.421-21	7.054-22	4.592-22
7.0	1.293-21	6.670-22	4.565-22
8.0	1.196-21	6.510-22	4.603-22
9.0	1.106-21	6.373-22	4.582-22
10.0	1.016-21	6.079-22	4.422-22
12.0	8.606-22	5.366-22	3.980-22
14.0	7.232-22	4.568-22	3.403-22
16.0	6.124-22	3.880-22	2.876-22
18.0	5.179-22	3.252-22	2.376-22
20.0	4.441-22	2.765-22	1.996-22
22.0	3.838-22	2.417-22	1.726-22
24.0	3.393-22	2.142-22	1.513-22
26.0	3.095-22	1.908-22	1.339-22
28.0	2.900-22	1.700-22	1.194-22
30.0	2.761-22	1.518-22	1.071-22
35.0	2.533-22	1.142-22	8.405-23
40.0	2.416-22	8.803-23	6.671-23
45.0	2.498-22	7.059-23	5.309-23
50.0	2.705-22	5.807-23	4.292-23
55.0	2.921-22	4.842-23	3.560-23
60.0	3.340-22	4.174-23	3.002-23
65.0	4.164-22	3.739-23	2.569-23
70.0	4.847-22	3.387-23	2.225-23
75.0	4.937-22	3.033-23	1.941-23
80.0	5.182-22	2.775-23	1.703-23
85.0		2.629-23	1.499-23

ES EV	EP = 250. EV	EP = 500. EV
90.0	2.491-23	1.325-23
95.0	2.288-23	1.181-23
100.0	2.180-23	1.062-23
110.0	2.159-23	8.813-24
120.0	2.313-23	7.476-24
130.0	2.528-23	6.354-24
140.0	2.946-23	5.634-24
150.0	3.573-23	5.305-24
160.0	4.488-23	4.974-24
170.0	5.624-23	4.530-24
180.0	7.220-23	4.029-24
190.0	9.495-23	3.473-24
200.0	1.226-22	3.122-24
220.0	1.721-22	2.968-24
240.0		2.953-24
260.0		3.096-24
280.0		3.520-24
300.0		4.330-24
320.0		5.413-24
340.0		7.231-24
360.0		9.712-24
380.0		1.335-23
400.0		1.932-23
420.0		2.921-23
440.0		5.446-23
460.0		7.527-23
480.0		7.243-23

Note: ES is ejected electron energy in eV and EP is primary electron energy.

Reference: These data were taken from R.D. DuBois and M.E. Rudd, Phys. Rev. A 17, 843 (1978).



Graphical Data I-1.B-5. Single differential cross section (secondary electron spectra) for $e^- + N_2$ collisions. These data were taken from E.C. Beaty, Radiation Research 64, 70 (1975).

Tabular Data I-1.B-6. Single differential cross sections (secondary electron spectra) for $e^- + H_2$ collisions (units of m^2/eV).

Primary Electron Energy = 100 eV

ES EV	H_2
4.0	3.472-22
5.0	3.393-22
6.0	3.265-22
7.0	3.051-22
8.0	2.797-22
9.0	2.522-22
10.0	2.267-22
12.0	1.846-22
14.0	1.545-22
16.0	1.260-22
18.0	1.126-22
20.0	1.009-22
22.0	8.894-23
24.0	8.250-23
26.0	7.252-23
28.0	7.020-23
30.0	6.483-23
35.0	5.875-23
40.0	5.602-23
45.0	5.782-23
50.0	6.588-23
55.0	7.758-23
60.0	9.660-23
65.0	1.270-22
70.0	1.644-22
75.0	2.110-22
80.0	2.702-22
85.0	3.241-22

Note: ES is ejected electron energy in eV.

Reference: These data were taken from R.D. DuBois and M.E. Rudd, Phys. Rev. A 17, 843 (1978).

Tabular Data I-1.B-7. Single differential cross sections (secondary electron spectra) for $e^- + H_2$ collisions (units of 10^{-20} cm^2/eV).

SECONDARY ENERGY (EV)	H_2
4.13	427.
4.32	4C7.
4.53	396.
4.74	3HC.
4.97	374.
5.21	359.
5.45	345.
5.71	337.
5.99	322.
6.27	311.
6.57	3C4.
6.88	284.
7.21	274.
7.6	264.
7.9	252.
8.3	239.
8.7	226.
9.1	214.
9.5	202.
10.C	191.
10.5	175.
11.0	162.
11.5	15C.
12.0	141.
12.6	131.
13.2	125.
13.8	117.
14.5	108.
15.2	98.
15.9	88.
16.7	82.
17.4	76.
18.3	71.3
19.1	66.5
20.1	61.2
21.C	56.9
22.C	52.3
23.1	4R.6
24.2	44.9
25.3	41.1
26.5	38.2
27.8	34.8
29.1	32.C
30.5	29.5
31.9	27.2
33.5	24.7
35.1	22.5
36.7	21.1
38.5	18.8
40.3	17.2

SECONDARY ENERGY (EV)	H_2
42.2	16.0
44.2	14.2
46.3	13.2
48.5	11.9
50.9	11.0
53.3	10.2
55.8	9.1
58.5	8.1
61.3	7.6
64.2	6.84
67.2	6.22
70.4	5.56
73.8	5.15
77.	4.67
81.	4.26
85.	3.79
89.	3.53
93.	3.14
98.	2.83
1C2.	2.53
107.	2.36
112.	2.14
117.	1.90
123.	1.73
129.	1.57
135.	1.44
141.	1.33
148.	1.22
155.	1.C7
163.	.98
170.	.89
179.	.81
187.	.77
196.	.703
205.	.684

Reference: These data were taken from C.B. Opal, E.C. Beaty, and W.K. Peterson, Atomic Data 4, 209 (1972).

Tabular Data I-1.B-8. Single differential cross sections (secondary electron spectra) for $e^- + H_2$ collisions (units of 10^{-18} cm^2/eV).

Energy (eV)	Impact Energy 1 keV	2.5 keV	5 keV	7.5 keV	10 keV
.50	3.68000	1.65300	.83200	.64960	.45760
.60	4.02500	1.57700	.80000	.61093	.45760
.80	3.85250	1.68150	.73600	.58000	.42240
1.00	2.60567	1.62450	.70400	.51427	.36667
1.40	2.57600	1.18370	.63147	.44931	.31035
2.00	2.03263	1.03407	.59067	.38319	.26547
3.00	1.44700	.74670	.46080	.28536	.21296
4.00	1.12700	.53010	.34560	.21808	.17424
5.00	.80500	.42180	.25920	.18560	.13024
6.00	.63633	.35160	.18880	.15030	.09856
8.00	.46575	.23370	.13280	.09744	.07392
10.00	.32392	.16626	.09547	.06573	.05955
14.00	.19358	.09937	.05749	.03851	.03115
20.00	.08491	.05192	.03061	.02198	.01742
30.00	.05175	.02451	.01120	.00719	.00810
40.00	.02763	.01311	.00608	.00510	.00422
50.00	.01495	.00570	.00352	.00348	.00317
60.00	.00920	.00266	.00267	.00224	.00223
80.00	.00518	.00114	.00096	.00070	.00079
100.00	.00403	.00086	.00027	.00019	.00038
140.00	.00035	.00017	.00010	.00007	.00005
200.00	.00000	.00000	.00000	.00000	.00000

Reference: These data were taken from D.A. Vroom, "Energy Deposition Studies. Final Report," IRT Corporation Report 7007-008, 1976 (unpublished).

Tabular Data I-1.B-9. Single differential cross sections (secondary electron spectra) for $e^- + C_2H_2$ collisions (units of 10^{-20} cm^2/eV).

Primary Electron Energy = 500 eV

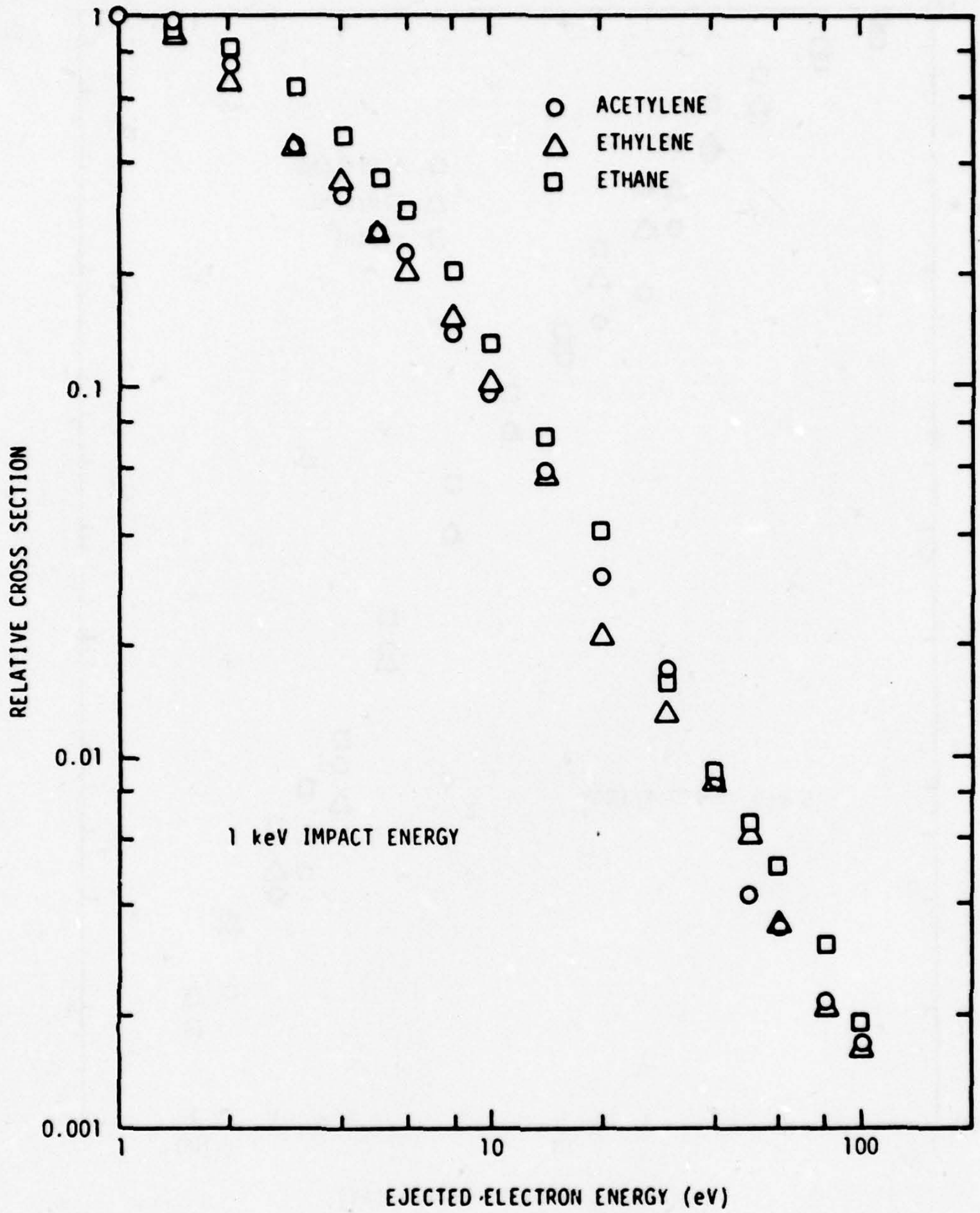
SECONDARY ENERGY (EV)	C_2H_2
4.13	1520.
4.32	1420.
4.53	1350.
4.74	1240.
4.97	1170.
5.21	1100.
5.45	1050.
5.71	1030.
5.99	990.
6.27	950.
6.57	950.
6.88	900.
7.21	880.
7.6	850.
7.9	790.
8.3	770.
8.7	735.
9.1	712.
9.5	682.
10.0	665.
10.5	644.
11.0	616.
11.5	586.
12.0	555.
12.6	524.
13.2	496.
13.8	463.
14.5	435.
15.2	406.
15.9	382.
16.7	359.
17.4	334.
18.3	314.
19.1	294.
20.1	270.
21.0	254.
22.0	234.
23.1	215.
24.2	198.
25.3	182.
26.5	167.
27.8	152.
29.1	139.
30.5	127.
31.9	116.
33.5	105.
35.1	97.
36.7	88.
38.5	80.
40.3	72.4
42.2	65.4
44.2	60.7
46.3	55.8
48.5	48.6
50.9	44.3
53.3	40.7
55.8	37.7
58.5	34.2
61.3	31.0
64.2	28.2
67.2	25.6
70.4	22.8
73.8	20.8
77.	18.9
81.	17.2
85.	15.5
89.	14.0
93.	13.1
98.	11.8
102.	10.7
107.	9.6
112.	8.6
117.	8.0
123.	7.15
129.	6.43
135.	6.00
141.	5.43
148.	4.92
155.	4.48
163.	4.12
170.	3.89
179.	3.51
187.	3.22
196.	3.11
205.	3.05

Reference: These data were taken from C.B. Opal, E.C. Beaty, and W.K. Peterson, Atomic Data 4, 209 (1972).

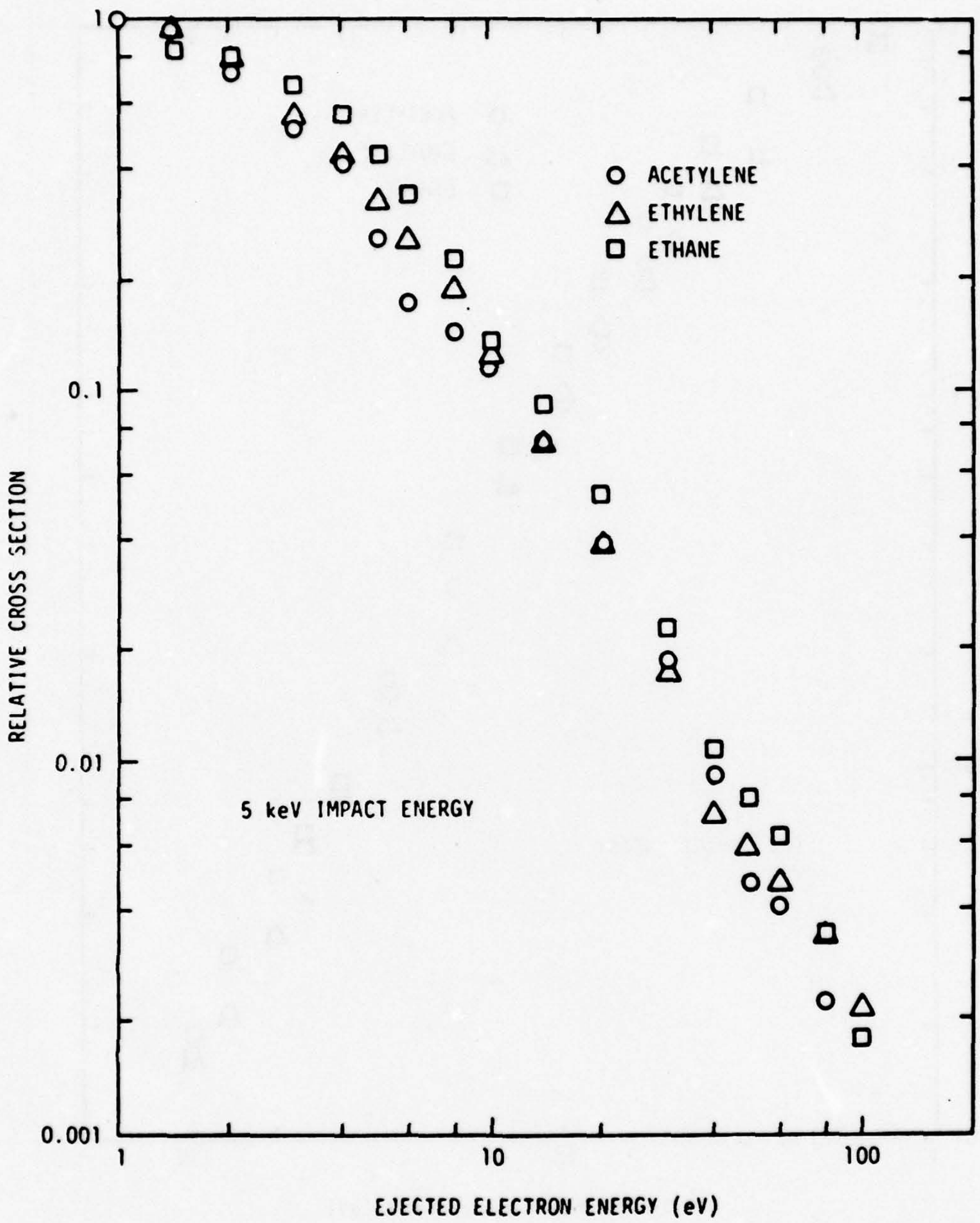
Tabular Data I-1.B-10. Single differential cross sections (secondary electron spectra) for $e^- + C_2H_2$ collisions (units of 10^{-18} cm^2/eV).

Energy (eV)	Impact Energy 1 keV	2.5 keV	5 keV	7.5 keV	10 keV
.50	22.07200	9.86595	5.83975	4.42225	3.99030
.60	21.77534	9.83592	5.81490	4.33200	3.91483
.80	21.09300	9.79837	5.59125	4.23688	3.67990
1.00	20.66283	9.63319	5.47943	4.12142	3.43137
1.40	19.71350	9.63609	5.17460	3.63286	2.91020
2.00	15.30133	7.29134	3.77807	2.60978	2.15516
3.00	9.52300	5.02758	2.83707	2.03604	1.51688
4.00	6.99540	3.52742	2.30359	1.63694	1.12351
5.00	5.34000	2.92825	1.36675	.99275	.77625
6.00	4.74667	2.48267	.95258	.69192	.66033
8.00	2.89250	1.68936	.80762	.58663	.45987
10.00	2.00250	1.31395	.65438	.46629	.33017
14.00	1.23117	.65322	.38932	.26172	.22640
20.00	.63042	.34914	.21226	.14666	.12027
30.00	.35600	.15768	.09940	.06679	.07075
40.00	.17800	.11262	.04970	.03610	.03537
50.00	.08900	.05856	.02485	.02347	.01415
60.00	.07417	.02853	.02319	.01805	.01179
80.00	.04450	.02703	.01243	.01354	.00708
100.00	.03708	.01727	.00538	.00752	.00590
140.00	.01928	.00646	.00472	.00391	.00307
200.00	.01261	.00477	.00193	.00256	.00200

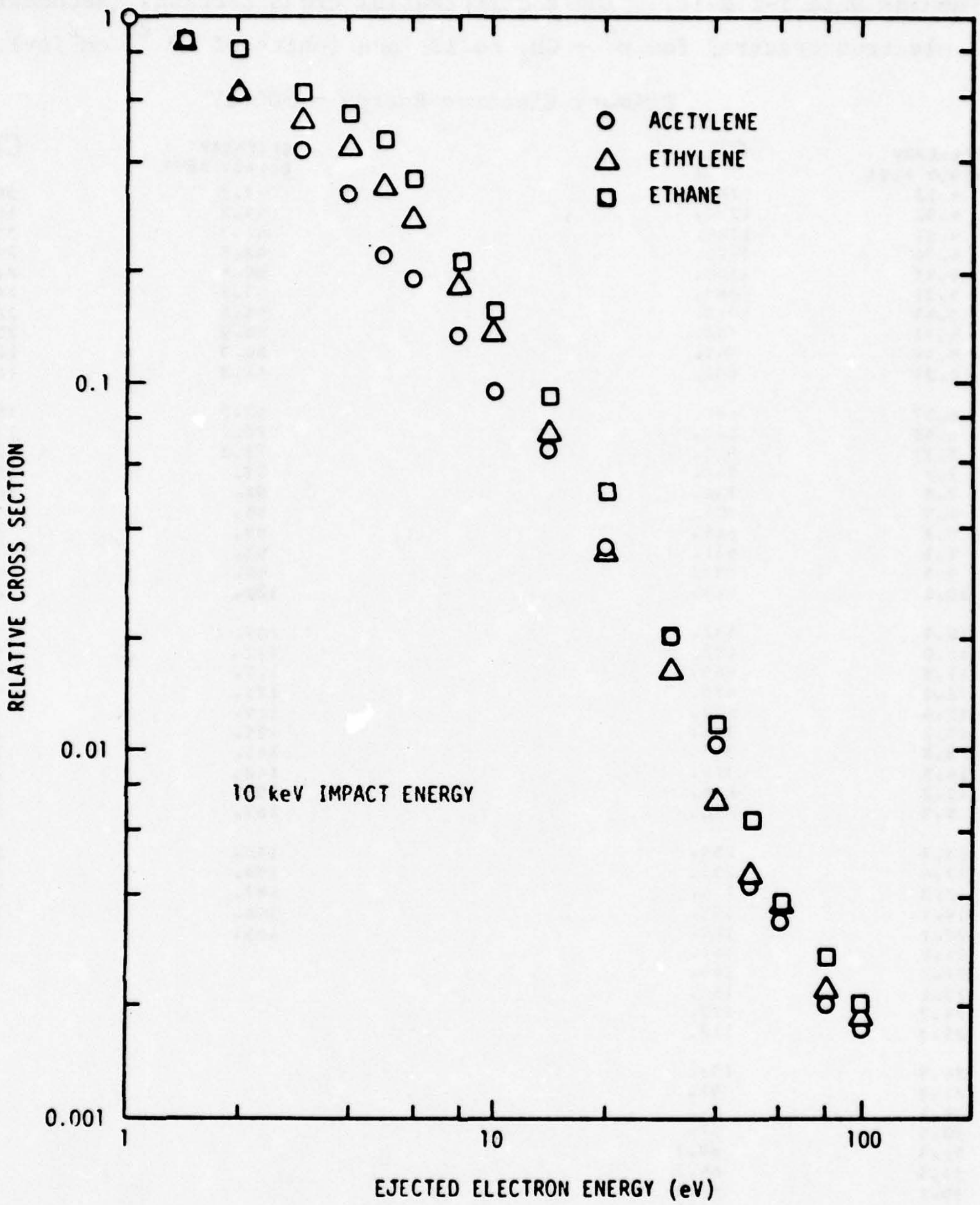
Reference: These data were taken from D.A. Vroom. "Energy Deposition Studies. Final Report," IRT Corporation Report 7007-008, 1976 (unpublished).



Graphical Data I-1.11. Comparison of single differential cross sections (secondary electron spectra) of C_2H_2, C_2H_4, and C_2H_6 ionized by 1 keV electrons. These data were taken from D.A. Vroom, "Energy Deposition Studies. Final Report," IRT Corporation Report 7007-008, 1968 (unpublished).



Graphical Data I-1.B-12. Comparison of single differential cross sections (secondary electron spectra) of C_2H_2, C_2H_4, and C_2H_6 ionized by 5 keV electrons. These data were taken from D.A. Vroom, "Energy Deposition Studies. Final Report," IRT Corporation Report 7007-008, 1968 (unpublished).



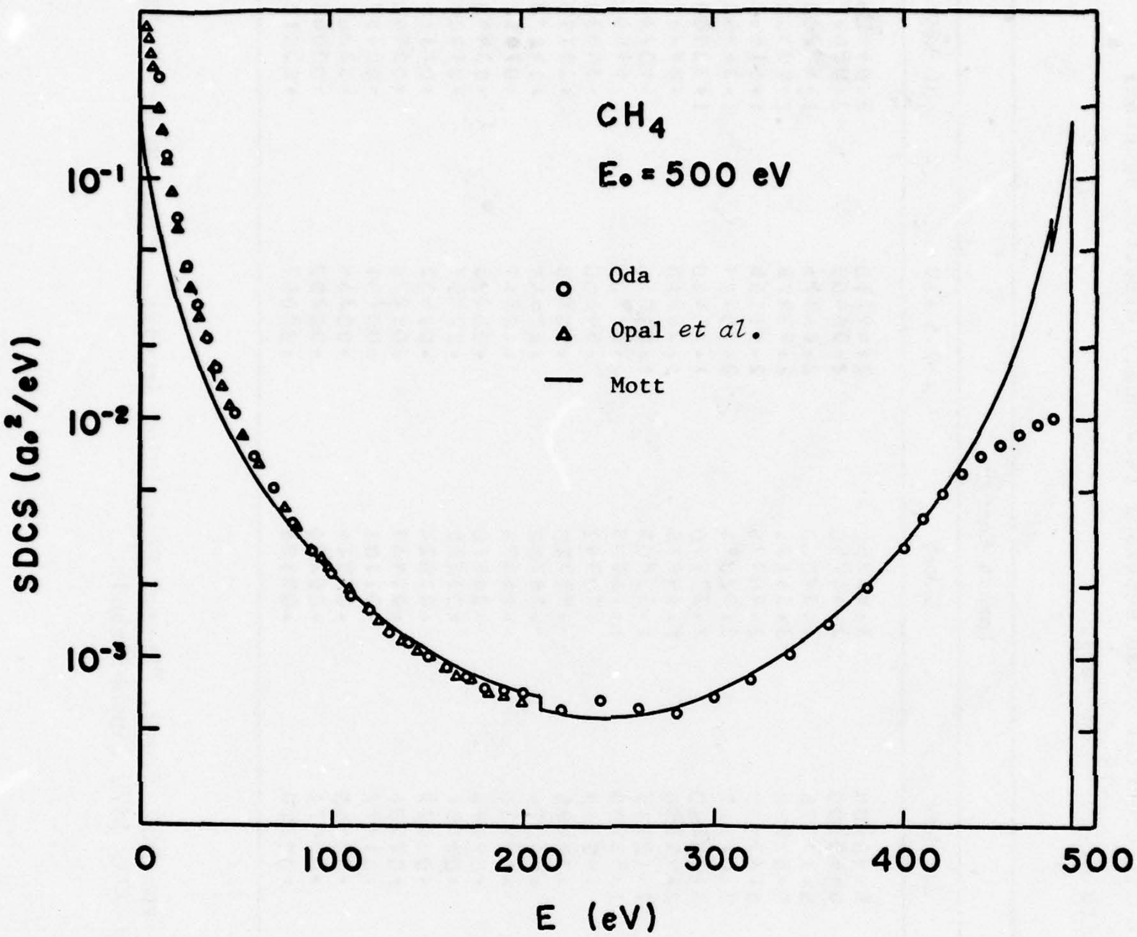
Graphical Data I-1.B-13. Comparison of single differential cross sections (secondary electron spectra) of C_2H_2, C_2H_4, and C_2H_6 ionized by 10 keV electrons. These data were taken from D.A. Vroom, "Energy Deposition Studies. Final Report," IRT Corporation Report 7007-008, 1968 (unpublished).

Tabular Data I-1.B-14. Single differential cross sections (secondary electron spectra) for $e^- + CH_4$ collisions (units of 10^{-20} cm^2/eV).

Primary Electron Energy = 500 eV

SECONDARY ENERGY (EV)	CH_4
4.13	1240.
4.32	1200.
4.53	1160.
4.74	1120.
4.97	1100.
5.21	1060.
5.45	1010.
5.71	980.
5.99	940.
6.27	890.
6.57	880.
6.88	820.
7.21	800.
7.6	760.
7.9	736.
8.3	704.
8.7	664.
9.1	631.
9.5	597.
10.0	569.
10.5	532.
11.0	493.
11.5	460.
12.0	436.
12.6	402.
13.2	381.
13.8	345.
14.5	319.
15.2	296.
15.9	270.
16.7	255.
17.4	233.
18.3	214.
19.1	195.
20.1	180.
21.0	161.
22.0	148.
23.1	136.
24.2	122.
25.3	112.
26.5	102.
27.8	92.
29.1	84.
30.5	77.
31.9	69.7
33.5	64.2
35.1	57.4
36.7	52.5
38.5	47.5
40.3	43.7
42.2	39.5
44.2	36.3
46.3	33.1
48.5	29.9
50.9	27.1
53.3	24.7
55.8	22.4
58.5	20.6
61.3	18.8
64.2	16.7
67.2	15.1
70.4	13.5
73.8	12.4
77.	11.1
81.	10.4
85.	9.1
89.	8.3
93.	7.7
98.	6.84
102.	6.26
107.	5.68
112.	5.05
117.	4.55
123.	4.18
129.	3.86
135.	3.50
141.	3.14
148.	2.86
155.	2.59
163.	2.40
170.	2.25
179.	2.06
187.	1.93
196.	1.87
205.	1.82

Reference: These data were taken from C.B. Opal, E.C. Beaty, and W.K. Peterson, Atomic Data 4, 209 (1972).

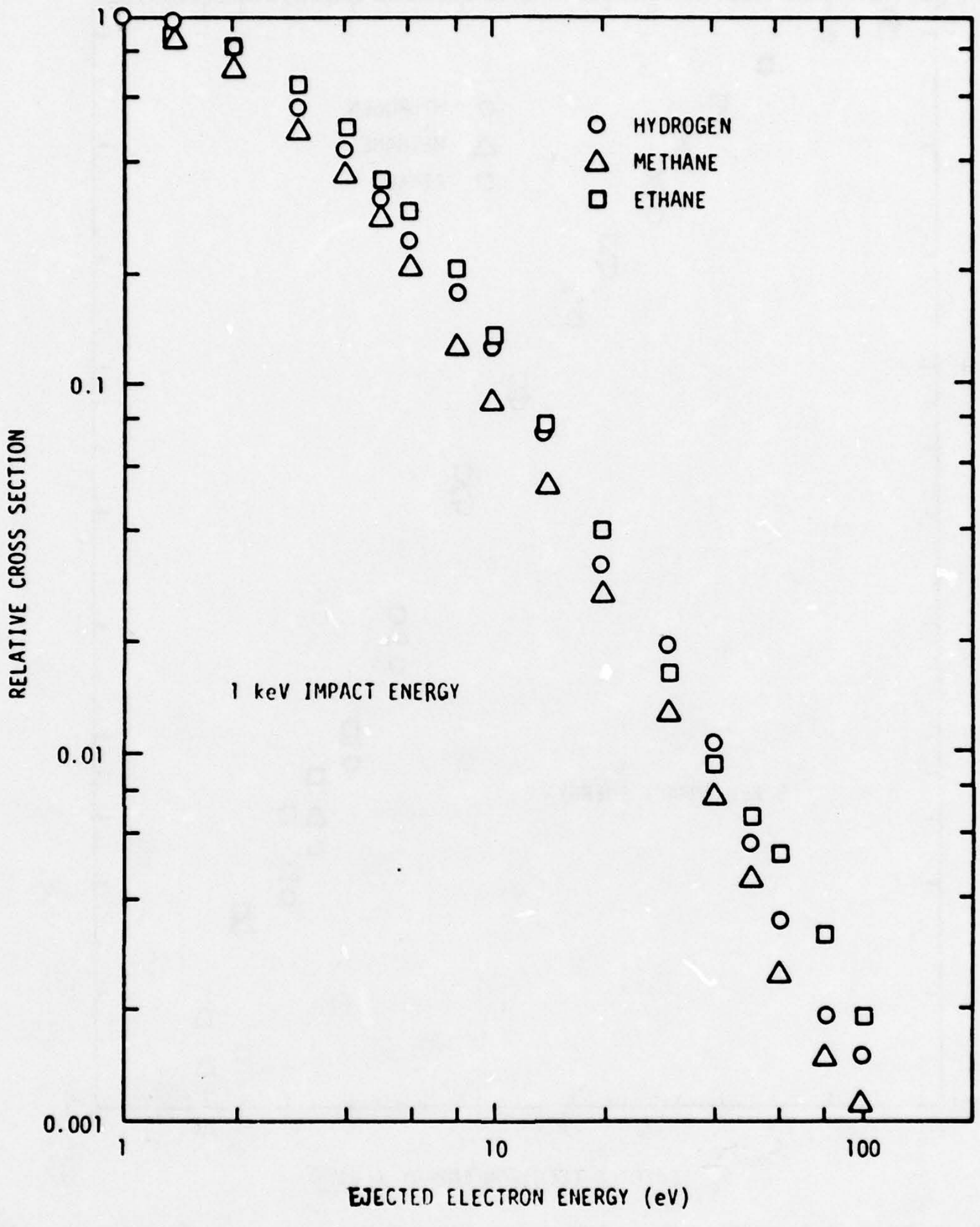


Graphical Data I-1.B-15. Single differential cross sections (secondary electron spectrum) for electron impact ionization of CH_4 in units of $a_o^2/eV = 2.80 \times 10^{-17}\ cm^2/eV$. This figure was taken from N. Oda, Radiat. Res. 64 (80), 1975. The Oda data are from that paper, the Opal et al. data are from C.B. Opal, E.C. Beaty, and W.K. Peterson, Atomic Data 4, 209 (1972), and the Mott curve is theoretical.

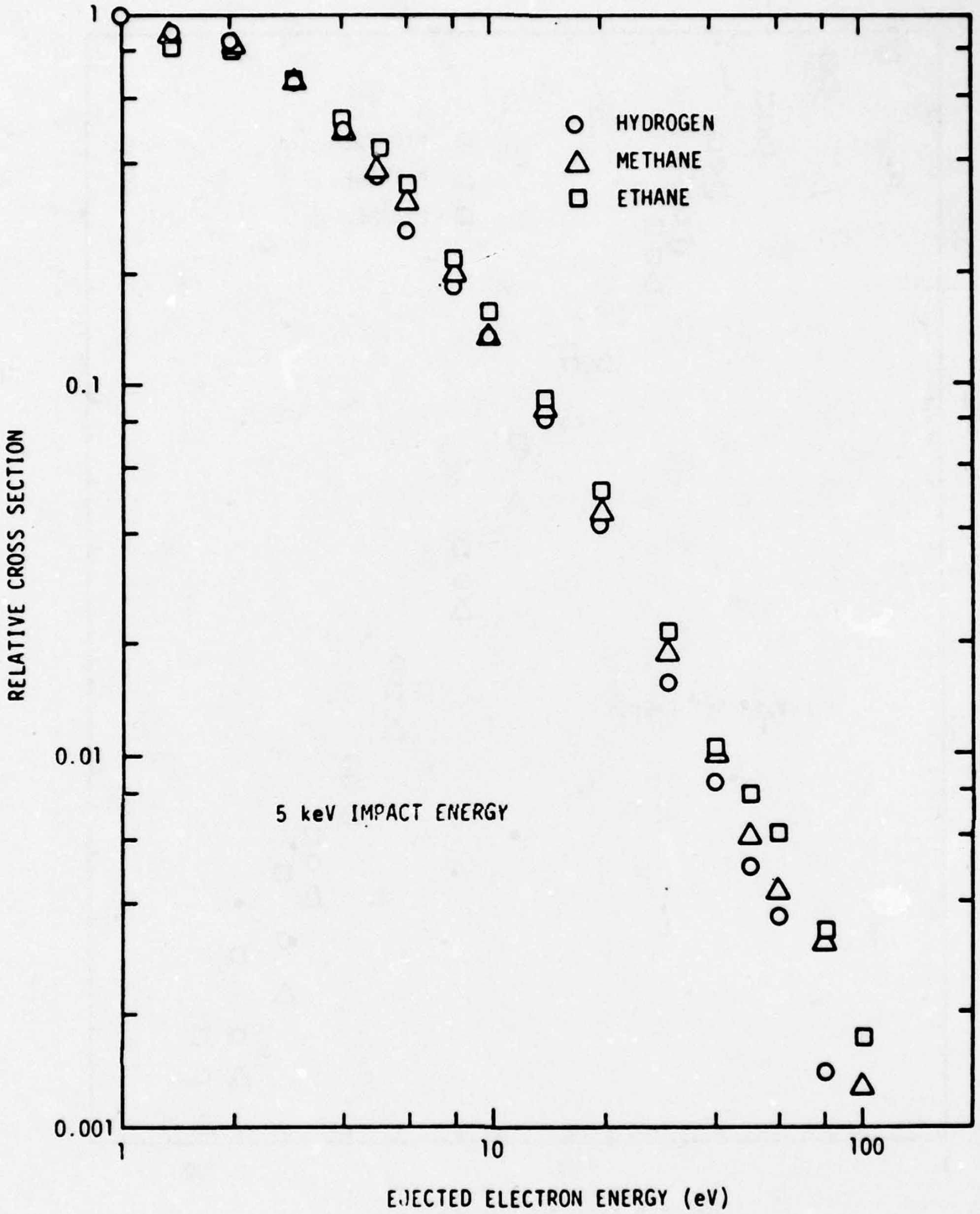
Tabular Data I-1.B-16. Single differential cross sections (secondary electron spectra) for $e^- + CH_4$ collisions (units of 10^{-18} cm^2/eV).

Energy (eV)	Impact Energy 1 keV	2.5 keV	5 keV	7.5 keV	10 keV
.50	21.98000	5.90700	3.55950	2.59350	2.06400
.60	22.24167	5.90790	3.55950	2.36600	2.00667
.80	19.62500	5.77275	3.39000	2.66175	1.89200
1.00	20.27917	5.63850	3.36175	2.93475	1.80600
1.40	19.65117	5.67430	2.90975	2.46155	1.51933
2.00	14.88229	5.07017	2.82075	2.10324	1.36453
3.00	10.20600	3.70680	2.33910	1.55610	1.20400
4.00	7.92850	2.95350	1.64415	1.28310	.84280
5.00	6.12300	2.12115	1.33905	1.01010	.60200
6.00	4.34367	1.53940	1.11305	.81900	.49880
8.00	2.59850	.95318	.70342	.54600	.34830
10.00	1.92325	.72495	.49720	.40950	.23793
14.00	1.10685	.40275	.28702	.27664	.14276
20.00	.57139	.19936	.16498	.12717	.07052
30.00	.26690	.09666	.06610	.05323	.03440
40.00	.15700	.05101	.03390	.02457	.01806
50.00	.09420	.03222	.02034	.01502	.01118
60.00	.05757	.02506	.01469	.01274	.00860
80.00	.04710	.01477	.01102	.00751	.00387
100.00	.03663	.00850	.00424	.00364	.00201
140.00	.01256	.00671	.00220	.00200	.00063
200.00	.00698	.00228	.00106	.00057	.00018

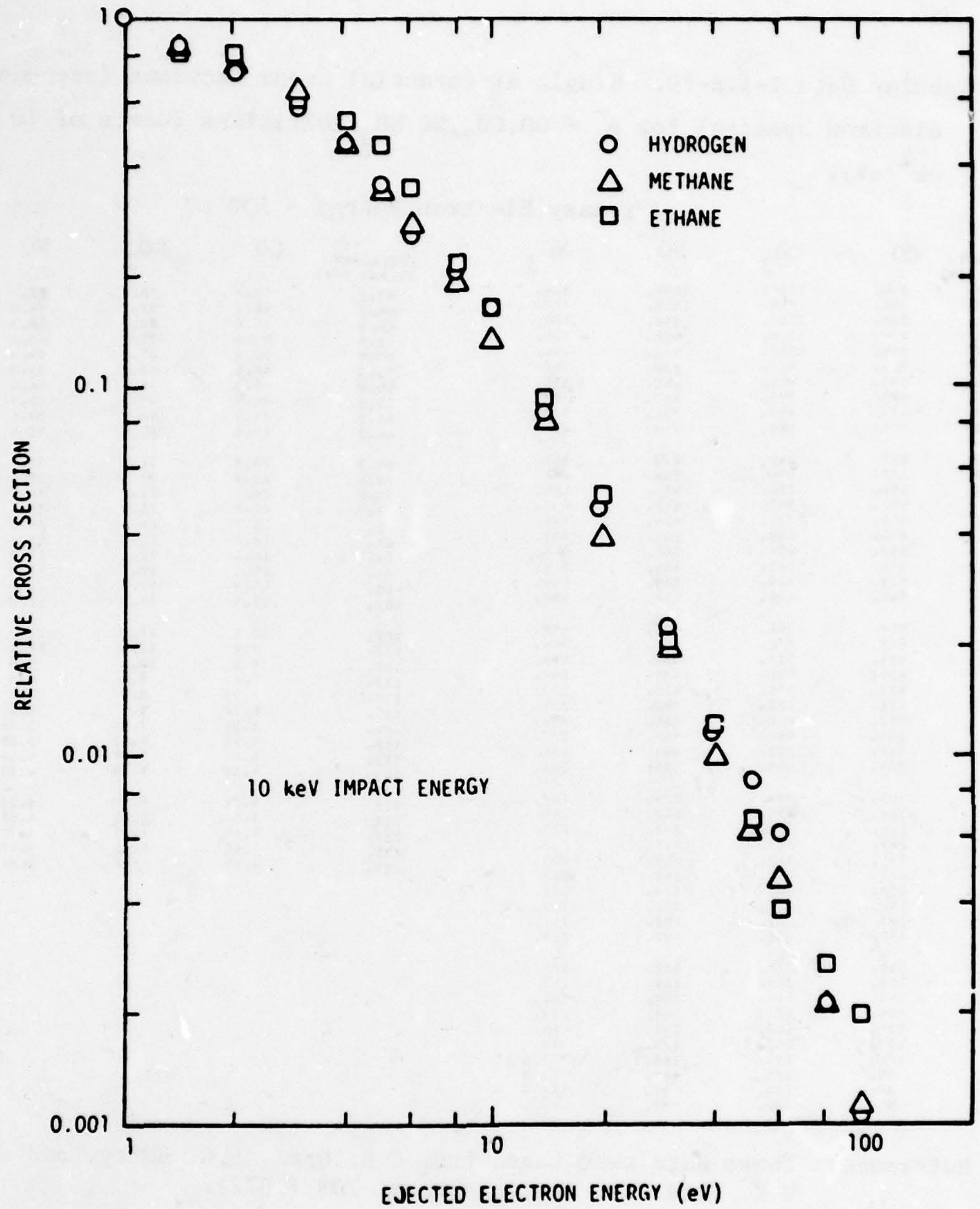
Reference: These data were taken from D.A. Vroom, "Energy Deposition Studies. Final Report," IRT Corporation Report 7007-008, 1976 (unpublished).



Graphical Data I-1.B-17. Comparison of single differential cross sections (secondary electron spectra) of H_2, CH_4, and C_2H_6 ionized by 1 keV electrons. These data were taken from D.A. Vroom, "Energy Deposition Studies. Final Report," IRT Corporation Report 7007-008, 1968 (unpublished).



Graphical Data I-1.B-18. Comparison of single differential cross sections (secondary electron spectra) of H_2, CH_4, and C_2H_6 ionized by 5 keV electrons. These data were taken from D.A. Vroom, "Energy Deposition Studies. Final Report," IRT Corporation Report 7007-008, 1968 (unpublished).



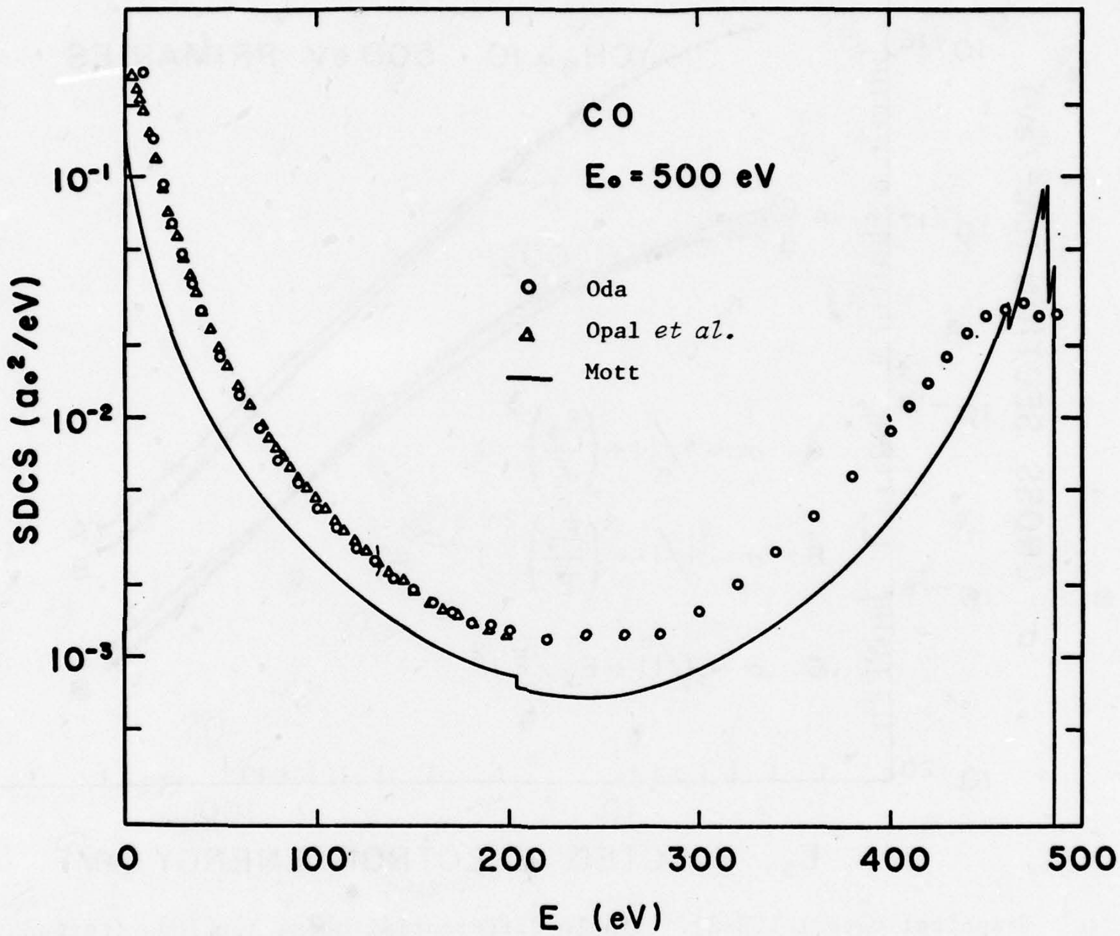
Graphical Data I-1.B-19. Comparison of single differential cross sections (secondary electron spectra) of H_2, CH_4, and C_2H_6 ionized by 10 keV electrons. These data were taken from D.A. Vroom, "Energy Deposition Studies. Final Report," IRT Corporation Report 7007-008, 1968 (unpublished).

Tabular Data I-1.B-20. Single differential cross sections (secondary electron spectra) for $e^- + CO, CO_2, NO, NH_3$ collisions (units of 10^{-20} cm^2/eV).

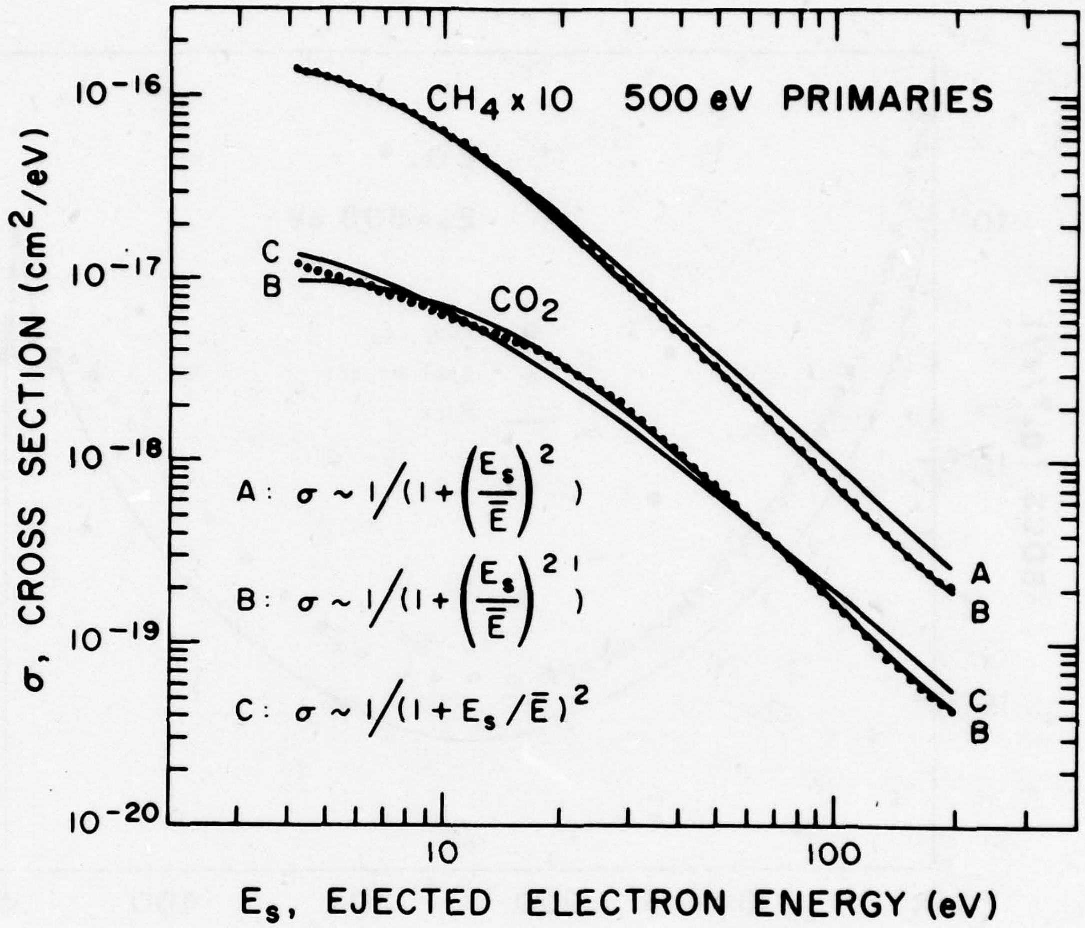
Primary Electron Energy = 500 eV

SECONDARY ENERGY (EV)	CO	CO_2	NO	NH_3
4.13	750.	1130.	1090.	800.
4.32	760.	1090.	1010.	790.
4.53	750.	1060.	950.	770.
4.74	734.	1020.	920.	770.
4.97	746.	1010.	910.	770.
5.21	725.	980.	880.	749.
5.45	693.	940.	850.	730.
5.71	683.	910.	810.	705.
5.99	675.	890.	770.	703.
6.27	650.	860.	748.	678.
6.57	639.	840.	723.	661.
6.88	609.	800.	704.	644.
7.21	596.	770.	676.	630.
7.6	595.	742.	648.	605.
7.9	603.	721.	629.	598.
8.3	606.	695.	601.	566.
8.7	593.	673.	590.	544.
9.1	576.	646.	565.	528.
9.5	573.	619.	539.	499.
10.0	545.	600.	518.	485.
10.5	517.	571.	492.	458.
11.0	502.	552.	470.	444.
11.5	483.	528.	452.	418.
12.0	459.	520.	431.	398.
12.6	433.	500.	413.	377.
13.2	416.	482.	397.	363.
13.8	392.	460.	381.	334.
14.5	366.	441.	368.	320.
15.2	349.	428.	351.	296.
15.9	323.	409.	331.	286.
16.7	303.	396.	324.	267.
17.4	286.	375.	302.	245.
18.3	261.	363.	292.	229.
19.1	247.	343.	274.	213.
20.1	233.	322.	262.	201.
21.0	226.	307.	248.	183.
22.0	209.	285.	234.	171.
23.1	192.	270.	220.	157.
24.2	183.	251.	207.	147.
25.3	172.	235.	191.	135.
26.5	163.	218.	182.	123.
27.8	150.	203.	169.	112.
29.1	142.	188.	155.	102.
30.5	129.	173.	148.	94.
31.9	121.	160.	135.	86.
33.5	112.	147.	125.	77.
35.1	103.	134.	115.	73.5
36.7	95.	125.	107.	64.9
38.5	89.	115.	99.	60.0
40.3	80.	104.	90.	55.8
42.2	72.6	96.	81.	49.5
44.2	68.5	88.	74.1	46.1
46.3	61.9	80.	68.3	41.4
48.5	57.0	72.1	63.6	37.6
50.9	50.5	65.6	56.8	34.5
53.3	47.4	60.3	51.3	31.1
55.8	42.5	54.7	46.6	28.3
58.5	40.1	48.8	42.7	26.2
61.3	35.0	44.7	38.6	23.8
64.2	33.0	40.5	35.8	21.5
67.2	28.9	36.2	31.8	19.0
70.4	26.8	32.9	28.5	17.5
73.8	24.1	29.8	26.1	16.4
77.	21.8	26.9	23.4	15.0
81.	19.7	24.5	21.3	13.2
85.	18.2	21.8	19.4	12.4
89.	16.4	19.6	17.8	10.4
93.	15.1	18.0	15.8	9.8
98.	13.8	15.8	14.2	8.7
102.	12.3	14.3	12.8	7.9
107.	10.8	13.0	11.6	7.48
112.	9.8	11.6	10.5	6.70
117.	8.8	10.6	9.6	6.01
123.	8.4	9.6	8.5	5.24
129.	7.38	8.9	7.7	4.91
135.	6.72	7.9	6.91	4.14
141.	6.25	7.16	6.15	3.88
148.	5.46	6.42	5.68	3.48
155.	4.84	5.85	5.11	3.17
163.	4.60	5.38	4.75	2.83
170.	4.21	4.99	4.32	2.55
179.	3.98	4.63	4.02	2.31
187.	3.69	4.31	3.72	2.29
196.	3.61	4.03	3.47	2.08
205.	3.59	4.01	3.31	1.80

Reference: These data were taken from C.B. Opal, E.C. Beaty, and W.K. Peterson, Atomic Data 4, 209 (1972).



Graphical Data I-1.B-21. Single differential cross sections (secondary electron spectrum) for electron impact ionization of CO in units of $a_o^2/eV = 2.80 \times 10^{-17}\ cm^2/eV$. This figure was taken from N. Oda, Radiat. Res. 64 (80), 1975. The Oda data are from that paper, the Opal et al. data are from C.B. Opal, E.C. Beaty, and W.K. Peterson, Atomic Data 4, 209 (1972), and the Mott curve is theoretical.



Graphical Data I-1.B-22. Single differential cross sections (secondary electron spectra) for $e^- + CO_2$, CH_4 collisions. These data were taken from C.B. Opal, W.K. Peterson, and E.C. Beaty, J. Chem. Phys. 55, 4100 (1971).

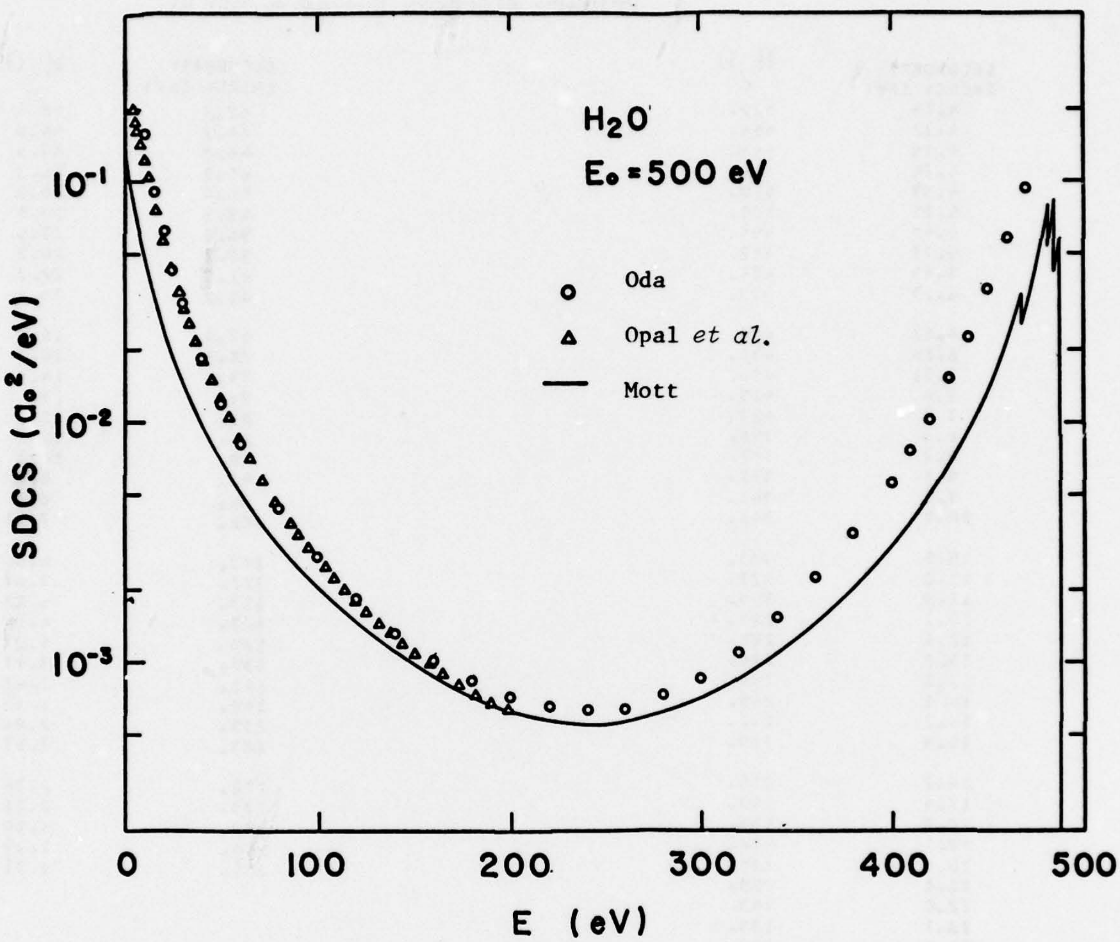
Tabular Data I-1.B-23. Single differential cross sections (secondary electron spectra) for $e^- + H_2O$ collisions (units of 10^{-20} cm^2/eV).

Primary Electron Energy = 500 eV

SECONDARY ENERGY (EV)	H_2O
4.13	572.
4.32	558.
4.53	548.
4.74	524.
4.97	519.
5.21	509.
5.45	495.
5.71	482.
5.99	474.
6.27	453.
6.57	458.
6.88	436.
7.21	430.
7.6	415.
7.9	403.
8.3	396.
8.7	382.
9.1	372.
9.5	361.
10.0	348.
10.5	333.
11.0	323.
11.5	309.
12.0	297.
12.6	285.
13.2	274.
13.8	255.
14.5	247.
15.2	231.
15.9	219.
16.7	210.
17.4	197.
18.3	185.
19.1	176.
20.1	165.
21.0	155.
22.0	143.
23.1	135.
24.2	127.
25.3	116.
26.5	109.
27.8	100.
29.1	95.
30.5	86.
31.9	80.
33.5	73.6
35.1	67.4
36.7	61.8
38.5	56.1
40.3	52.7

SECONDARY ENERGY (EV)	H_2O
42.2	48.4
44.2	44.0
46.3	39.5
48.5	36.3
50.9	33.3
53.3	30.5
55.8	27.5
58.5	24.8
61.3	22.2
64.2	20.3
67.2	18.6
70.4	16.5
73.8	14.8
77.	13.8
81.	12.2
85.	11.2
89.	10.1
93.	8.8
98.	8.1
102.	7.21
107.	6.50
112.	5.87
117.	5.22
123.	4.69
129.	4.27
135.	3.77
141.	3.47
148.	3.13
155.	2.86
163.	2.67
170.	2.36
179.	2.11
187.	1.94
196.	1.79
205.	1.71

Reference: These data were taken from C.B. Opal, E.C. Beaty, and W.K. Peterson, Atomic Data 4, 209 (1972).

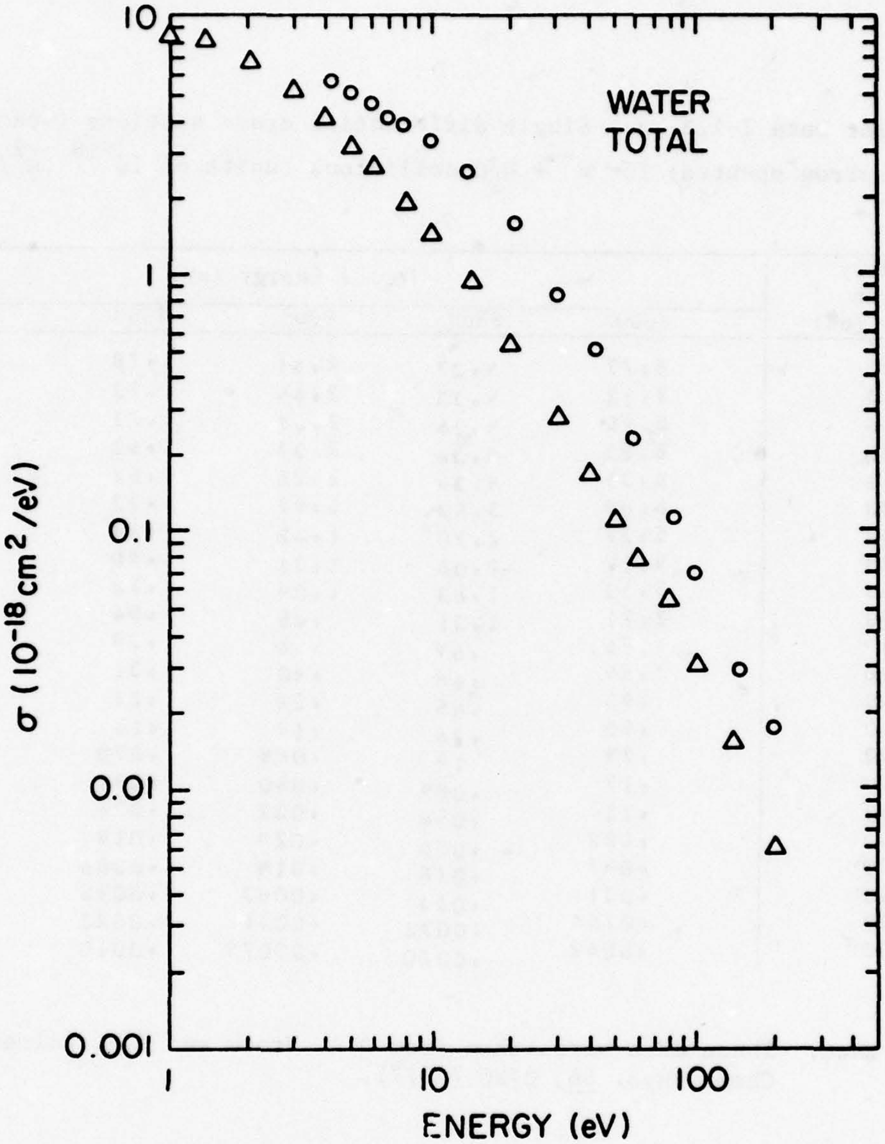


Graphical Data I-1.B-24. Single differential cross sections (secondary electron spectrum) for electron impact ionization of H_2O in units of $a_o^2/eV = 2.80 \times 10^{-17}\ cm^2/eV$. This figure was taken from N. Oda, Radiat. Res. 64, 80 (1975). The Oda data are from that paper, the Opal et al. data are from C.B. Opal, E.C. Beaty, and W.K. Peterson, Atomic Data 4, 209 (1972), and the Mott curve is theoretical.

Tabular Data I-1.B-25. Single differential cross sections (secondary electron spectra) for $e^- + H_2O$ collisions (units of 10^{-18} cm^2/eV).

Secondary Electron Energy (eV)	Impact Energy (eV)				
	1000	2500	5000	7500	10000
.50	8.77	4.27	2.61	1.78	1.31
.60	9.12	4.33	2.64	1.73	1.31
.80	8.95	4.36	2.39	1.73	1.36
1.00	8.83	4.36	2.37	1.62	1.29
1.40	8.31	4.24	2.26	1.52	1.19
2.00	6.89	3.53	1.97	1.33	1.01
3.00	5.37	2.70	1.62	1.12	.81
4.00	4.17	2.06	1.31	.90	.66
5.00	3.33	1.63	1.04	.72	.54
6.00	2.71	1.31	.85	.56	.45
8.00	1.96	.89	.56	.39	.33
10.00	1.49	.68	.40	.31	.26
14.00	.93	.45	.28	.21	.16
20.00	.55	.26	.17	.13	.10
30.00	.29	.14	.089	.070	.054
40.00	.17	.089	.050	.041	.028
50.00	.11	.056	.032	.026	.021
60.00	.082	.036	.024	.018	.019
80.00	.047	.018	.014	.0086	.0076
100.00	.031	.013	.0087	.0045	.0042
140.00	.015	.0072	.0036	.0023	.0019
200.00	.0062	.0020	.00079	.0010	.00069

Reference: These data were taken from D.A. Vroom and R.L. Palmer, J. Chem. Phys. 66, 3720 (1977).



Graphical Data I-1.B-26. Single differential cross sections (secondary electron spectra) for $e^- + H_2O$ collisions for 500 eV (o) and 1000 eV (Δ).

These data were taken from D.A. Vroom and R.L. Palmer, J. Chem. Phys. 66, 3720, (1977); the 1000 eV data are from the previous reference and the 500 eV data are from C.B. Opal, E.C. Beaty, and W.K. Peterson, Atomic Data 4, 209 (1972).

Section I-1.C. SECONDARY ELECTRON ENERGY SPECTRA FOR ELECTRON IMPACT IONIZATION

Data Needed

I. Free Atoms:

A) Noble Gases:

1. Ne - Electron impact energies below 100 eV and above 500 eV to several keV.
2. Ar - Energies below 100 eV.
3. Kr - Energies below 500 eV and above 1 keV to several keV.
4. Xe - Energies below 500 eV and above 500 eV to several keV.

B) Other Free Atoms: No secondary electron spectra for electron impact ionization of other free atoms exist! Thus, data are needed for electron impact energies from about 50 eV to several keV.

II. Molecules (Monomers):

A) Diatomics:

1. H_2 - Electron impact energies below 100 eV, between 100 eV and 500 eV, and between 500 eV and 1 keV.
2. CO - Energies below 500 eV and above 500 eV to several keV.
3. NO - Energies below 500 eV and above 500 eV to several keV.
4. HF, HCl, HBr, HI, F_2, I_2 - NO DATA EXIST; data needed from about 50 eV to several keV.

B) Polyatomics:

1. CO_2 - Energies below 500 eV and above 500 eV to several keV.
2. CH_4 - Energies below 500 eV and between 500 eV and 1 keV.
3. NH_3 - Energies below 500 eV and above 500 eV to several keV.
4. C_2H_2 - Energies below 500 eV and between 500 eV and 1 keV.
5. H_2O - Energies below 500 eV and between 500 eV and 1 keV.
6. UF_6 - NO DATA EXIST; 50 eV to several keV needed.
7. N_2O - NO DATA EXIST; 50 eV to several keV needed.

III. Molecules (Dimers and Excimers): NO DATA EXIST; data are needed for electron impact energies from about 50 eV to several keV for all combinations of noble gas with noble gas and halogen atoms. This is meant to include clusters as well.

IV. Excited States of Atoms and Molecules: NO DATA EXIST; data are needed over the entire energy range for the metastable and other long-lived excited states of all of the atoms and molecules of interest.

I-2. ENERGY SPECTRA OF SECONDARY ELECTRONS FROM PROTON IMPACT IONIZATION

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Section I-2.A. SECONDARY ELECTRON ENERGY SPECTRA FOR PROTON IMPACT IONIZATION OF THE NOBLE GASES He, Ar, AND Xe

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Tabular Data I-2.A-1. Single differential cross section (secondary electron spectra) for H^+ + He collisions (units of cm^2/eV).

Electron Energy (eV)	Proton Energy (keV) 5	7	10	15	20	30	50	70	100
1.5	3.20-18	2.46-18	2.54-18	2.05-18	1.87-18	1.94-18	2.02-18	2.28-18	2.53-18
2.0	4.20-18	3.60-18	3.56-18	2.90-18	2.43-18	2.35-18	2.47-18	2.72-18	3.00-18
3.0	4.32-18	4.50-18	4.56-18	4.36-18	4.20-18	3.25-18	3.25-18	3.42-18	3.76-18
5.0	2.68-18	3.05-18	4.16-18	4.11-18	3.91-18	3.96-18	4.26-18	4.16-18	3.96-18
7.5	1.17-18	1.51-18	2.29-18	3.06-18	3.14-18	3.22-18	3.54-18	3.56-18	3.34-18
10.0	5.74-19	8.18-19	1.32-18	1.94-18	2.45-18	2.59-18	2.89-18	2.92-18	2.74-18
15.0	1.97-19	3.26-19	5.04-19	8.55-19	1.16-18	1.75-18	2.19-18	2.24-18	2.04-18
20.0	8.84-20	1.55-19	2.36-19	4.23-19	6.30-19	1.03-18	1.69-18	1.82-18	1.65-18
30.0	2.78-20	4.33-20	7.95-20	1.54-19	2.31-19	4.55-19	9.55-19	1.23-18	1.17-18
50.0	5.02-21	4.54-21	1.19-20	2.83-20	4.28-20	1.24-19	3.43-19	5.11-19	6.53-19
75.0	9.19-22	4.65-22	1.24-21	4.65-21	8.40-21	2.55-20	1.14-19	2.00-19	2.85-19
100.0	8.36-22	1.19-22	1.82-22	7.09-22	1.50-21	5.94-21	3.88-20	9.21-20	1.45-19
130.0	• • •	9.67-24	2.42-22	1.00-22	3.88-22	1.17-21	1.03-20	3.46-20	7.23-20
160.0	7.20-23	1.10-23	7.63-23	1.12-22	1.25-22	3.80-22	2.82-21	1.21-20	3.62-20
200.0	• • •	• • •	3.41-23	2.47-24	1.32-23	7.22-23	5.04-22	2.58-21	1.24-20
250.0	1.24-23	2.03-22	4.66-23	4.63-23	3.54-23	2.76-23	6.37-23	4.28-22	2.96-21
300.0	• • •	7.16-23	4.69-24	• • •	• • •	9.34-25	1.59-23	8.70-23	6.78-22

Reference: These data were taken from M. E. Rudd, L. H. Toburen, and N. Stolterfoht, Atomic Data and Nuclear Data Tables 18, 413 (1976).

Tabular Data I-2.A-2. Single differential cross section (secondary electron spectra) for H^+ + He collisions (units of cm^2/eV).

Electron Energy (eV)	Proton Energy 50 keV	100 keV	150 keV
1.0	2.89-18	3.16-18	2.36-18
1.2	2.99-18	3.23-18	2.45-18
1.5	3.09-18	3.34-18	2.61-18
2.0	3.05-18	3.33-18	2.70-18
2.5	2.90-18	3.13-18	2.63-18
3.0	2.83-18	2.99-18	2.55-18
4.0	2.75-18	2.79-18	2.42-18
5.0	2.63-18	2.56-18	2.22-18
6.0	2.55-18	2.44-18	2.05-18
8.0	2.51-18	2.21-18	1.85-18
10.0	2.35-18	2.00-18	1.64-18
12.0	2.24-18	1.80-18	1.51-18
15.0	2.09-18	1.62-18	1.32-18
20.0	1.74-18	1.40-18	1.10-18
25.0	1.33-18	1.21-18	9.27-19
30.0	9.39-19	1.06-18	7.97-19
40.0	5.75-19	8.59-19	6.33-19
50.0	3.36-19	6.40-19	5.07-19
60.0	2.17-19	4.42-19	4.03-19
80.0	8.89-20	2.29-19	2.62-19
100.0	3.66-20	1.33-19	1.56-19
120.0	1.46-20	8.15-20	1.03-19
150.0	4.04-21	3.99-20	5.98-20
200.0	4.05-22	1.08-20	2.63-20
250.0	2.46-22	2.51-21	1.20-20
300.0	7.08-23	7.64-22	4.89-21
400.0	1.98-23	1.12-23	6.03-22
500.0		5.56-24	6.79-23

Reference: These data were taken from M. E. Rudd, L. H. Toburen, and N. Stolterfoht, Atomic Data and Nuclear Data Tables 18, 413 (1976).

Tabular Data I-2.A-3. Single differential cross section (secondary electron spectra) for H^+ + He collisions (units of cm^2/eV).

Electron Energy (eV)	Proton Energy 100 keV	200 keV	300 keV
2.0	3.99-18	3.17-18	2.64-18
4.0	3.91-18	2.99-18	2.50-18
6.0	3.59-18	2.69-18	2.27-18
8.0	3.28-18	2.43-18	1.99-18
10.0	2.94-18	2.13-18	1.75-18
15.0	2.35-18	1.62-18	1.28-18
20.0	1.87-18	1.26-18	9.99-19
25.0	1.58-18	1.02-18	7.89-19
30.0	1.31-16	8.35-19	6.62-19
35.0	1.21-18	7.69-19	5.85-19
40.0	9.89-19	6.20-19	4.73-19
50.0	7.20-19	4.55-19	3.37-19
60.0	5.06-19	3.49-19	2.53-19
70.0	3.52-19	2.74-19	2.03-19
80.0	2.60-19	2.21-19	1.56-19
90.0	1.90-19	1.79-19	1.23-19
100.0	1.49-19	1.45-19	1.06-19
125.0	7.69-20	8.96-20	6.71-20
150.0	4.23-20	5.78-20	4.75-20
175.0	2.28-20	3.87-20	3.33-20
200.0	1.22-20	2.71-20	2.44-20
250.0	3.41-21	1.44-20	1.42-20
300.0	6.50-22	8.15-21	8.97-21
350.0	1.89-22	4.59-21	5.93-21
400.0	4.86-23	2.25-21	3.94-21
450.0	1.25-23	9.77-22	2.79-21
500.0		4.39-22	1.97-21
550.0		1.99-22	1.31-21
600.0		8.59-23	7.85-22
650.0		3.61-23	4.57-22
700.0		1.74-23	2.41-22
750.0		1.13-23	1.37-22
800.0		3.00-24	5.02-23
850.0		8.97-25	2.97-23
900.0		1.07-24	1.27-23
950.0			6.96-24

Reference: These data were taken from M. E. Rudd, L. H. Toburen, and N. Stolterfoht, Atomic Data and Nuclear Data Tables 18, 413 (1976).

Tabular Data I-2.A-4. Single differential cross section (secondary electron spectra) for H^+ + He collisions (units of cm^2/eV).

Electron Energy (eV)	Proton Energy 300 keV	1.0 MeV	1.5 MeV
0.0	1.69-18	8.93-19	1.12-18
1.0	1.69-18	9.77-19	1.04-18
2.0	1.88-18	9.14-19	8.94-19
4.0	1.89-18	7.66-19	6.90-19
6.0	1.63-18	6.43-19	5.64-19
8.0	1.44-18	5.40-19	4.78-19
10.0	1.26-18	4.66-19	4.13-19
15.0	8.96-19	3.30-19	2.90-19
20.0	6.76-19	2.51-19	2.24-19
30.0	4.65-19	1.64-19	1.40-19
40.0	3.34-19	1.10-19	8.86-20
50.0	2.49-19	7.80-20	6.06-20
60.0	1.91-19	5.83-20	4.42-20
70.0	1.56-19	4.43-20	3.36-20
80.0	1.27-19	3.55-20	2.64-20
90.0	1.04-19	2.90-20	2.12-20
100.0	8.70-20	2.40-20	1.74-20
150.0	4.26-20	1.13-20	7.97-21
200.0	2.37-20	6.44-21	4.57-21
250.0	1.48-20	4.19-21	2.93-21
300.0	9.63-21	2.91-21	2.01-21
350.0	6.82-21	2.16-21	1.53-21
400.0	4.91-21	1.59-21	1.12-21
450.0	3.41-21	1.29-21	8.48-22
500.0	2.42-21	1.03-21	6.74-22
550.0	1.56-21	8.53-22	5.43-22
600.0	9.23-22	7.07-22	4.57-22
650.0	4.99-22	5.97-22	3.93-22
700.0	2.49-22	5.17-22	3.43-22
750.0	1.18-22	4.54-22	3.04-22
800.0	5.05-23	4.04-22	2.68-22
850.0	1.83-23	3.58-22	2.37-22
900.0	6.34-24	3.21-22	2.11-22
950.0	5.47-25	2.87-22	1.90-22
1000.0		2.58-22	1.71-22
1100.0		2.16-22	1.42-22
1200.0		1.83-22	1.22-22
1300.0		1.58-22	1.07-22
1400.0		1.38-22	9.34-23
1500.0		1.19-22	8.08-23
1750.0		8.59-23	6.18-23
2000.0		4.82-23	4.70-23
2250.0		1.37-23	3.72-23
2500.0		2.25-24	2.93-23
2750.0		3.25-25	2.16-23
3000.0			1.43-23
3500.0			1.46-24

Note: The low electron energy portion in these data was taken with a time-of-flight system and, thus, should be accurate down to about 1 eV.

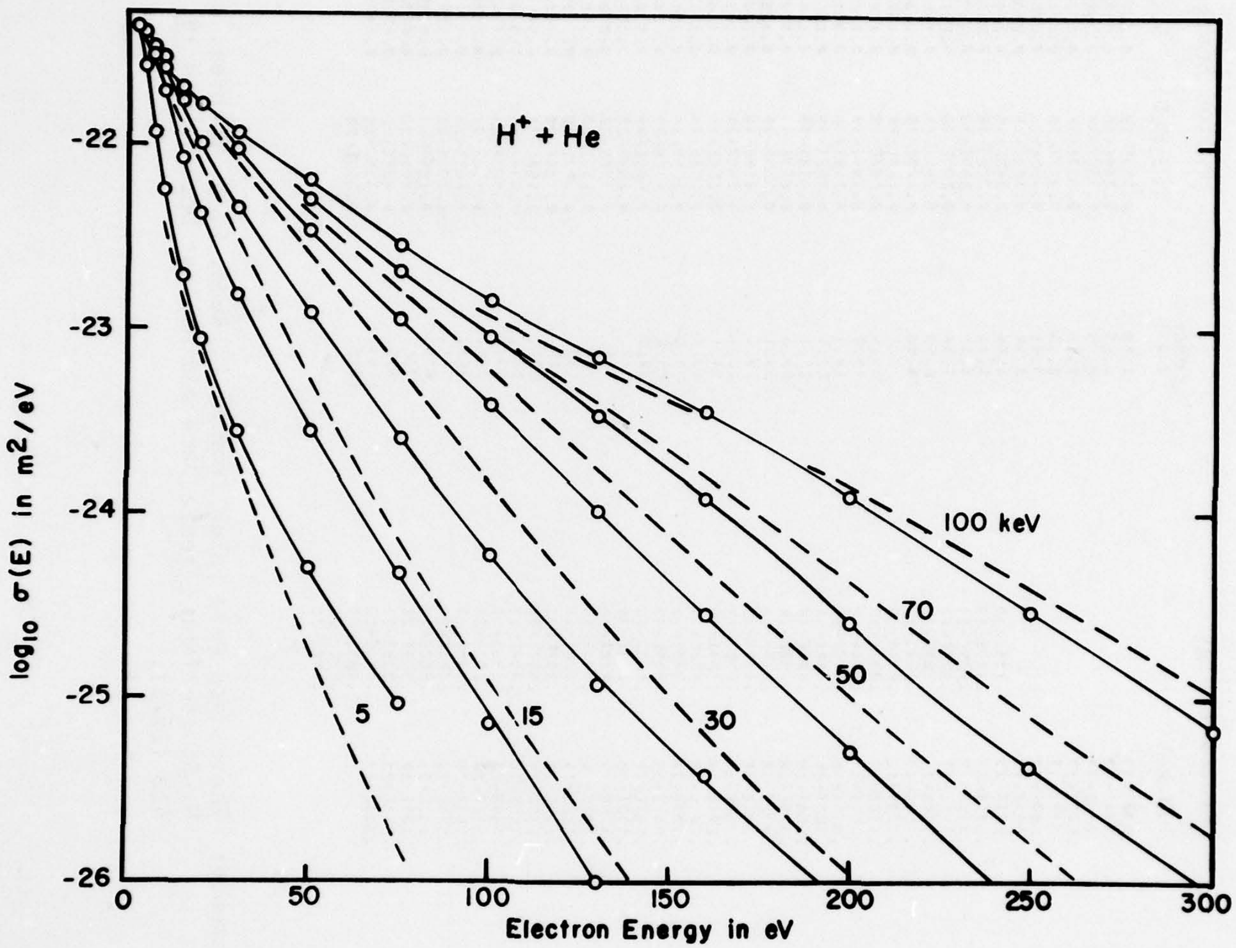
Reference: These data were taken from M. E. Rudd, L. H. Toburen, and N. Stolterfoht, Atomic Data and Nuclear Data Tables 18, 413 (1976).

Tabular Data I-2.A-5. Single differential cross section (secondary electron spectra) for H^{+} + He collisions (units of cm^{2}/eV).

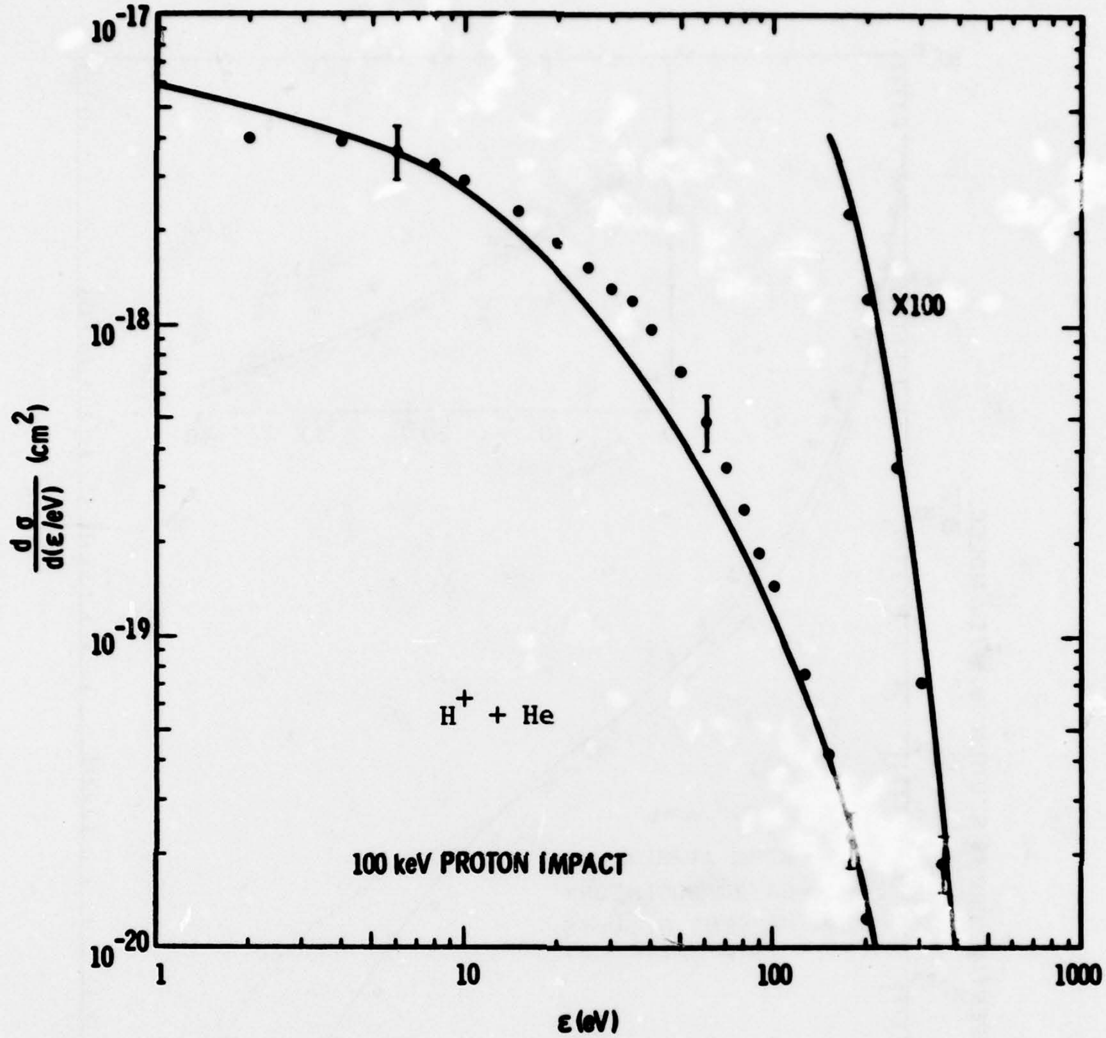
ENERGY (EV)	Proton Energy 300 keV	Proton Energy 500 keV
1.85	.208F-17	
2.15	.204E-17	
2.51	.212E-17	
2.93	.205E-17	
3.41	.210E-17	
3.98	.220E-17	
4.64	.221F-17	
5.41	.221E-17	.155E-17
6.31	.217E-17	.147E-17
7.36	.210E-17	.139E-17
8.58	.195E-17	.123E-17
10.00	.178E-17	.109E-17
11.7	.157E-17	.984E-18
13.6	.137E-17	.873E-18
15.8	.118E-17	.775E-18
18.5	.101E-17	.674E-18
21.5	.864E-18	.576E-18
25.1	.725E-18	.488E-18
29.3	.608E-18	.402E-18
34.1	.559E-18	.372E-18
39.8	.419E-18	.268E-18
46.4	.321E-18	.199E-18
54.1	.260E-18	.158E-18
63.1	.204E-18	.124E-18
73.6	.161E-18	.970E-19
85.8	.127E-18	.740E-19
100.0	.966E-19	.559E-19
117.	.741E-19	.423E-19
136.	.555E-19	.314E-19
158.	.418E-19	.230E-19
185.	.307E-19	.171E-19
215.	.222E-19	.128E-19
251.	.155E-19	.952E-20
293.	.110E-19	.692E-20
341.	.795E-20	.498E-20
398.	.569E-20	.356E-20
464.	.350E-20	.251E-20
541.	.163E-20	.175E-20
631.	.529E-21	.123E-20
736.	.133E-21	.862E-21
858.	.305E-22	.589E-21
1000.	.853E-23	.230E-21
1166.	.211E-23	.476E-22
1359.		.795E-23
1589.		.220E-23
1848.		.120E-23

ENERGY (EV)	Proton Energy 4.2 MeV	Proton Energy 5.0 MeV
1.58	0.357E-18	0.261E-18
1.85	0.348E-18	0.252E-18
2.15	0.336E-18	0.260E-18
2.51	0.327E-18	0.273E-18
2.93	0.317E-18	0.271E-18
3.41	0.325E-18	0.288E-18
3.98	0.327E-18	0.283E-18
4.64	0.342E-18	0.274E-18
5.41	0.328E-18	0.263E-18
6.31	0.299E-18	0.247E-18
7.36	0.275E-18	0.221E-18
8.58	0.241E-18	0.192E-18
10.00	0.220E-18	0.180E-18
11.7	0.188E-18	0.149E-18
13.6	0.163E-18	0.136E-18
15.8	0.140E-18	0.112E-18
18.5	0.118E-18	0.961E-19
21.5	0.980E-19	0.802E-19
25.1	0.816E-19	0.669E-19
29.3	0.655E-19	0.558E-19
34.1	0.553E-19	0.476E-19
39.8	0.418E-19	0.330E-19
46.4	0.309E-19	0.241E-19
54.1	0.224E-19	0.184E-19
63.1	0.172E-19	0.131E-19
73.6	0.125E-19	0.101E-19
85.8	0.937E-20	0.726E-20
100.0	0.689E-20	0.530E-20
117.	0.484E-20	0.368E-20
136.	0.350E-20	0.278E-20
158.	0.256E-20	0.198E-20
185.	0.187E-20	0.139E-20
215.	0.131E-20	0.105E-20
251.	0.960E-21	0.669E-21
293.	0.694E-21	0.540E-21
341.	0.503E-21	0.379E-21
398.	0.355E-21	0.262E-21
464.	0.243E-21	0.191E-21
541.	0.177E-21	0.125E-21
631.	0.129E-21	0.912E-22
736.	0.895E-22	0.627E-22
858.	0.638E-22	0.422E-22
1166.	0.335E-22	0.247E-22
1359.	0.232E-22	

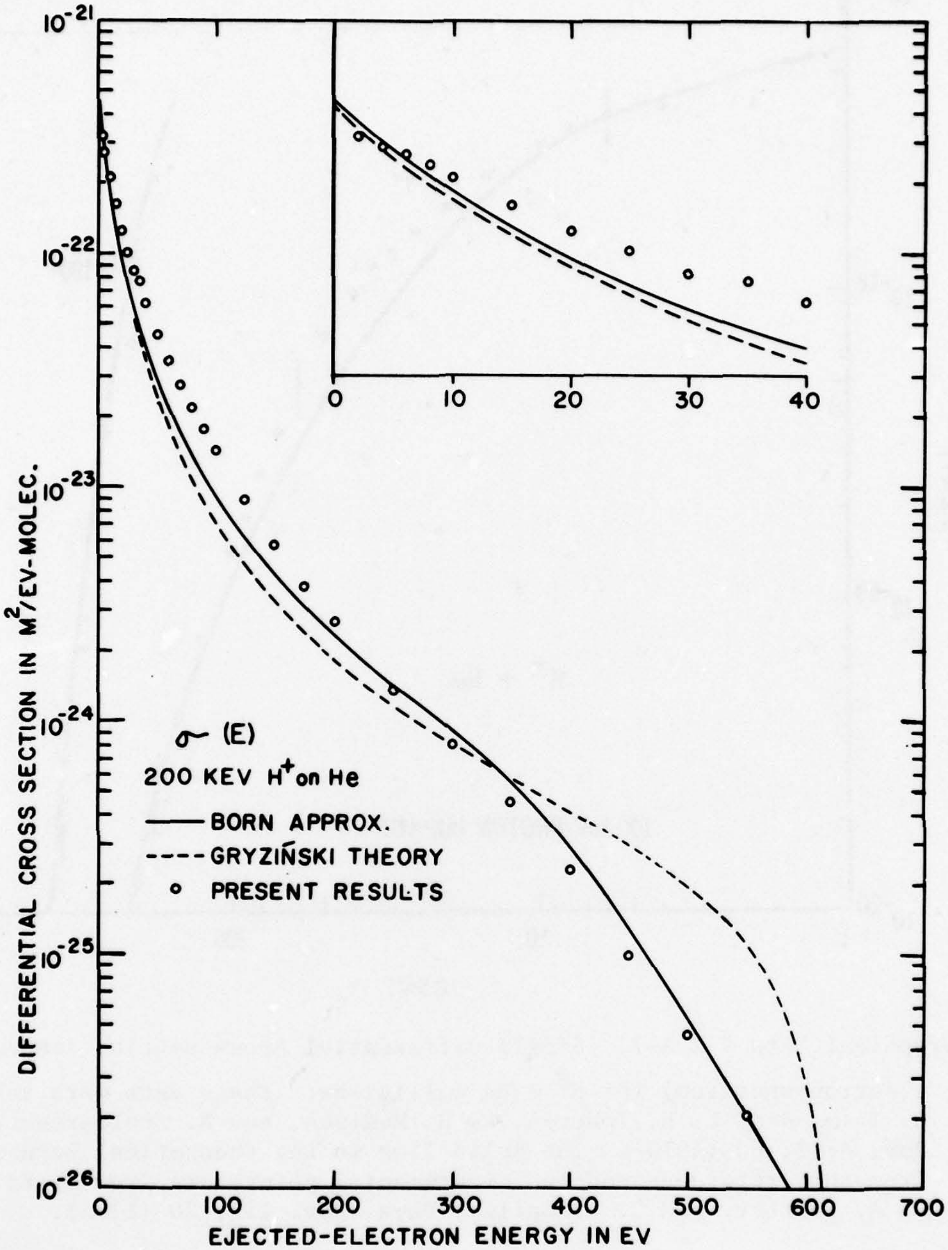
Reference: These data were taken from M. E. Rudd, L. H. Toburen, and N. Stolterfoht, Atomic Data and Nuclear Data Tables <u>18</u>, 413 (1976).



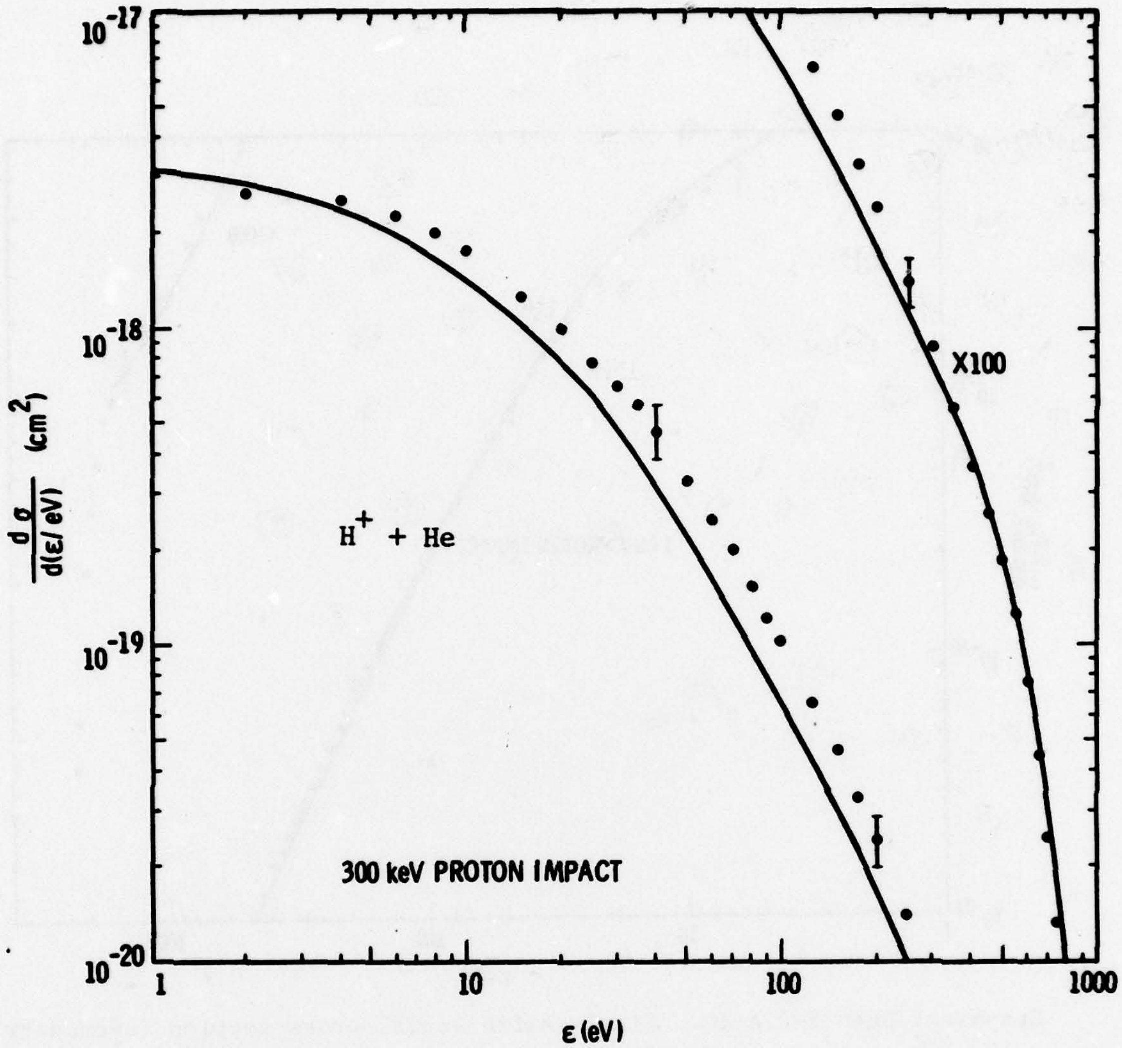
Graphical Data I-2.A-6. Single differential cross section (secondary electron spectrum) for H^+ + He collisions. These data were taken from M. E. Rudd and D. H. Madison, Phys. Rev. A 14, 128 (1976). The open circles and solid lines are experimental results, while the dashed lines are theoretical Born approximation results.



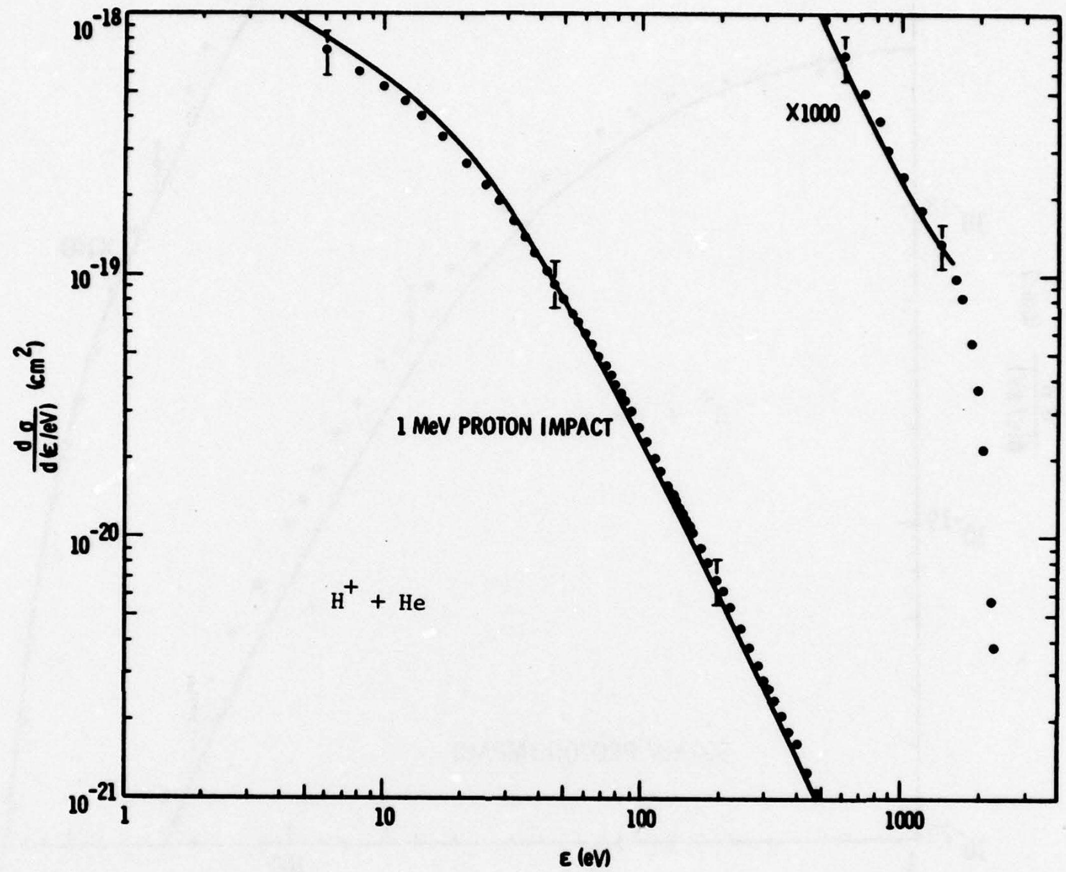
Graphical Data I-2.A-7. Single differential cross section (secondary electron spectrum) for H^+ + He collisions. These data were taken from S. T. Manson, L. H. Toburen, D. H. Madison, and N. Stolterfoht, Phys. Rev. A 12, 60 (1975). The solid line is the theoretical Born result from that reference and the experimental points are from M. E. Rudd, C. A. Sautter, and C. L. Bailey, Phys. Rev. 151, 20 (1966).



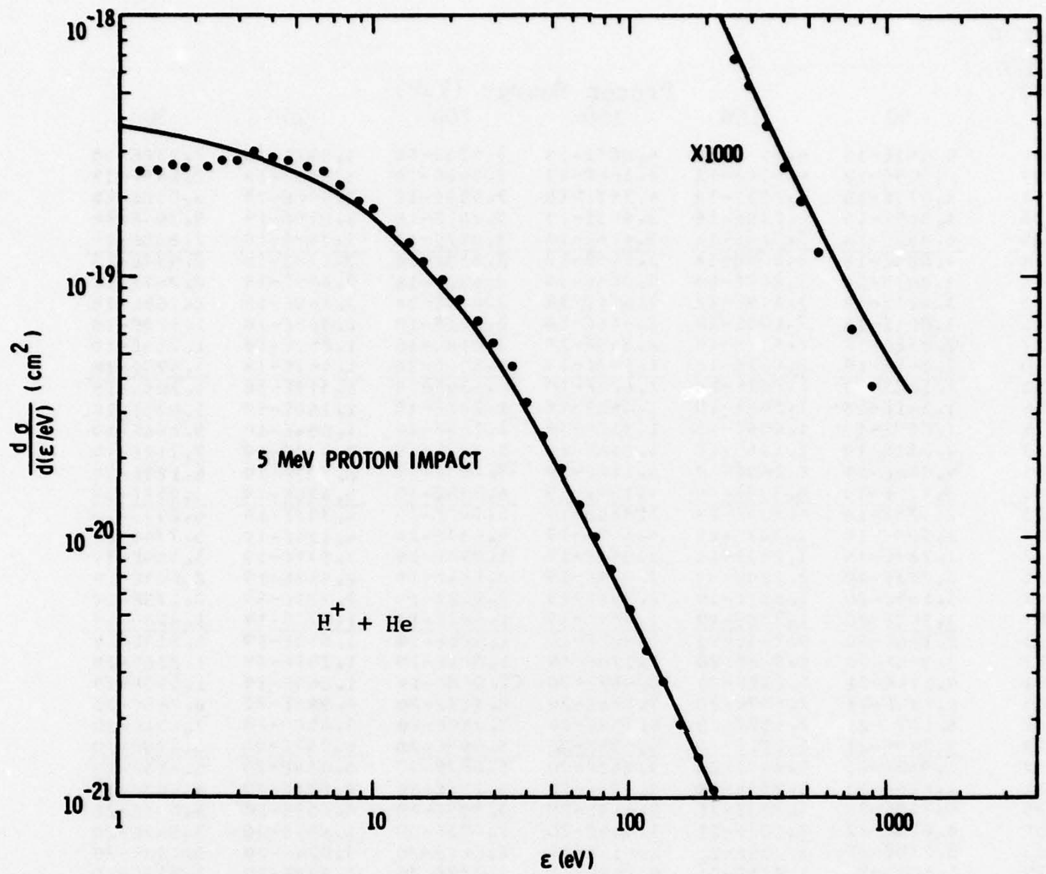
Graphical Data I-2.A-8. Single differential cross section (secondary electron spectrum) for H^+ + He collisions. These data were taken from M. E. Rudd, C. A. Sautter, and C. L. Bailey, Phys. Rev. 151, 20 (1966).



Graphical Data I-2.A-9. Single differential cross section (secondary electron spectrum) for H^+ + He collisions. These data were taken from S. T. Manson, L. H. Toburen, D. H. Madison, and N. Stolterfoht, Phys. Rev. A 12, 60 (1975). The solid line is the theoretical Born result from that reference and the experimental points are from M. E. Rudd, C. A. Sautter, and C. L. Bailey, Phys. Rev. 151, 20 (1966).



Graphical Data I-2.A-10. Single differential cross section (secondary electron spectrum) for H^+ + He collisions. These data were taken from S. T. Manson, L. H. Toburen, D. H. Madison, and N. Stolterfoht, Phys. Rev. A 12, 60 (1975). The points are experimental and the solid line is Born approximation theory.



Graphical Data I-2.A-11. Single differential cross section (secondary electron spectrum) for H^+ + He collisions. These data were taken from S. T. Manson, L. H. Toburen, D. H. Madison, and N. Stolterfoht, Phys. Rev. A 12, 60 (1975). The points are experimental and the solid line is Born approximation theory.

Tabular Data I-2.A-12. Single differential cross section (secondary electron spectra) for H^+ + Ne collisions (units of cm^2/eV).

Electron Energy (eV)	Proton Energy (keV) 50	100	150	200	250	300
0.0	4.591E-18	4.394E-18	4.085E-18	3.573E-18	3.297E-18	2.838E-18
1.49	4.895E-18	4.520E-18	4.166E-18	3.541E-18	3.266E-18	2.895E-18
3.41	5.673E-18	4.893E-18	4.383E-18	3.589E-18	3.300E-18	3.038E-18
5.34	4.885E-18	4.219E-18	3.881E-18	3.289E-18	3.035E-18	3.794E-18
7.26	4.352E-18	3.780E-18	3.485E-18	3.022E-18	2.798E-18	2.630E-18
9.18	4.025E-18	3.506E-18	3.245E-18	2.835E-18	2.635E-18	2.437E-18
11.11	3.843E-18	3.287E-18	3.008E-18	2.630E-18	2.465E-18	2.267E-18
13.03	3.625E-18	3.119E-18	2.674E-18	2.498E-18	2.349E-18	2.163E-18
17.15	3.001E-18	2.605E-18	2.416E-18	2.161E-18	1.983E-18	1.825E-18
21.27	2.872E-18	2.479E-18	2.259E-18	2.019E-18	1.851E-18	1.713E-18
25.40	2.241E-18	2.062E-18	1.897E-18	1.685E-18	1.547E-18	1.479E-18
29.52	1.562E-18	1.751E-18	1.623E-18	1.439E-18	1.317E-18	1.204E-18
33.64	1.341E-18	1.564E-18	1.450E-18	1.282E-18	1.160E-18	1.072E-18
37.76	1.099E-18	1.404E-18	1.310E-18	1.164E-18	1.054E-18	9.646E-19
47.38	7.231E-19	1.114E-18	1.056E-18	9.327E-19	8.373E-19	7.717E-19
57.00	4.846E-19	8.260E-19	8.614E-19	7.493E-19	6.703E-19	6.123E-19
66.62	3.425E-19	6.309E-19	7.157E-19	6.298E-19	5.610E-19	5.059E-19
76.23	2.425E-19	4.809E-19	5.925E-19	5.390E-19	4.796E-19	4.297E-19
85.85	1.765E-19	3.792E-19	4.840E-19	4.637E-19	4.124E-19	3.774E-19
95.47	1.267E-19	3.032E-19	3.948E-19	3.796E-19	3.577E-19	3.169E-19
109.21	8.232E-20	2.230E-19	2.978E-19	3.184E-19	2.947E-19	2.603E-19
122.95	5.185E-20	1.651E-19	2.299E-19	2.502E-19	2.425E-19	2.173E-19
136.69	3.340E-20	1.238E-19	1.785E-19	1.982E-19	1.977E-19	1.613E-19
150.43	2.186E-20	9.160E-20	1.420E-19	1.506E-19	1.593E-19	1.518E-19
164.17	1.396E-20	6.926E-20	1.128E-19	1.286E-19	1.297E-19	1.258E-19
177.91	9.174E-21	5.212E-20	8.962E-20	1.048E-19	1.069E-19	1.043E-19
191.65	6.174E-21	3.907E-20	7.176E-20	8.715E-20	8.945E-20	8.769E-20
205.39	4.103E-21	2.952E-20	5.734E-20	7.230E-20	7.450E-20	7.421E-20
219.13	2.749E-21	2.222E-20	4.598E-20	5.997E-20	6.357E-20	6.279E-20
232.87	1.938E-21	1.647E-20	3.751E-20	5.067E-20	5.464E-20	5.413E-20
246.61	1.429E-21	1.238E-20	3.028E-20	4.256E-20	4.688E-20	4.667E-20
260.35	9.309E-22	9.213E-21	2.469E-20	3.595E-20	4.052E-20	4.095E-20
274.09	6.603E-22	7.002E-21	1.964E-20	2.993E-20	3.481E-20	3.562E-20
287.83	5.230E-22	5.253E-21	1.619E-20	2.540E-20	3.024E-20	3.133E-20
342.79	1.603E-22	1.824E-21	6.798E-21	1.317E-20	1.720E-20	1.929E-20
397.75	5.905E-23	6.512E-22	2.828E-21	6.744E-21	1.004E-20	1.215E-20
452.71	3.880E-23	2.360E-22	1.199E-21	3.269E-21	5.806E-21	7.519E-21
507.67	1.339E-23	9.431E-23	4.987E-22	1.629E-21	3.283E-21	4.830E-21
562.63		4.833E-23	2.367E-22	7.988E-22	1.802E-21	3.062E-21
617.59		2.219E-23	1.200E-22	3.962E-22	1.024E-21	1.855E-21
727.51		1.175E-23	4.297E-23	1.241E-22	3.327E-22	7.051E-22
837.43		5.755E-24	1.584E-23	3.724E-23	1.145E-22	2.564E-22
947.35			6.242E-24	7.947E-24	3.041E-23	7.564E-23
1057.27				1.268E-24	1.117E-23	2.952E-23

Reference: These data were taken from J. B. Crooks and M. E. Rudd, Phys. Rev. A 3, 1628 (1974).

Tabular Data I-2.A-13. Single differential cross section (secondary electron spectra) for $H^+ + Ne$ collisions (units of cm^2/eV).

Proton Energy = 300 keV

ELECTRON ENERGY (EV)	SIGMA(E)	ELECTRON ENERGY (EV)	SIGMA(E)	ELECTRON ENERGY (EV)	SIGMA(E)	ELECTRON ENERGY (EV)	SIGMA(E)
0.0	2.58E-18	304.6	2.84E-20	651.4	1.63E-21	996.9	3.31E-23
1.4	3.05E-18	311.6	2.71E-20	657.1	1.59E-21	1002.5	3.65E-23
2.8	2.97E-18	318.7	2.59E-20	664.1	1.43E-21	1009.6	2.91E-23
5.6	2.79E-18	325.7	2.45E-20	671.2	1.40E-21	1018.0	3.38E-23
8.5	2.44E-18	332.8	2.31E-20	678.2	1.39E-21	1025.1	3.43E-23
11.3	2.18E-18	338.4	2.20E-20	685.3	1.22E-21	1030.7	2.98E-23
14.1	1.93E-18	345.5	2.06E-20	692.3	1.19E-21	1037.8	1.84E-23
16.9	1.76E-18	352.5	1.94E-20	699.4	1.03E-21	1044.8	1.56E-23
19.7	1.61E-18	361.0	1.83E-20	706.4	1.00E-21	1051.9	1.56E-23
22.6	1.47E-18	366.6	1.74E-20	712.1	9.85E-22	1060.3	1.15E-23
28.2	1.23E-18	373.7	1.61E-20	719.1	9.01E-22		
35.3	1.01E-18	380.7	1.57E-20	727.6	8.52E-22		
42.3	8.56E-19	367.8	1.47E-20	733.2	8.13E-22		
47.9	7.59E-19	393.4	1.40E-20	740.3	8.03E-22		
55.0	6.44E-19	401.9	1.33E-20	747.3	7.65E-22		
59.2	5.93E-19	408.9	1.19E-20	754.4	7.50E-22		
69.1	4.87E-19	416.0	1.14E-20	761.4	7.70E-22		
76.1	4.28E-19	421.6	1.14E-20	768.5	7.48E-22		
83.2	3.82E-19	428.6	1.04E-20	774.1	7.54E-22		
90.2	3.36E-19	435.7	9.82E-21	782.6	7.98E-22		
97.3	3.05E-19	442.7	9.56E-21	769.6	7.75E-22		
104.3	2.76E-19	451.2	8.72E-21	796.7	8.24E-22		
110.0	2.53E-19	455.4	8.75E-21	803.7	6.62E-22		
117.0	2.31E-19	463.9	8.02E-21	809.3	5.87E-22		
125.5	2.01E-19	470.9	7.49E-21	816.4	4.80E-22		
129.7	1.93E-19	478.0	7.35E-21	823.4	3.36E-22		
138.2	1.73E-19	483.6	7.03E-21	829.1	3.67E-22		
145.2	1.59E-19	490.7	6.60E-21	837.5	2.86E-22		
152.3	1.46E-19	497.7	6.29E-21	844.6	2.65E-22		
159.3	1.34E-19	506.2	5.61E-21	851.6	2.33E-22		
166.4	1.21E-19	511.8	5.52E-21	857.3	2.38E-22		
173.4	1.11E-19	518.9	5.22E-21	864.3	1.76E-22		
180.5	1.02E-19	525.9	5.09E-21	872.8	2.01E-22		
187.5	9.36E-20	533.0	4.59E-21	679.8	1.68E-22		
193.2	8.80E-20	538.6	4.51E-21	885.5	1.83E-22		
200.2	8.05E-20	547.1	4.23E-21	892.5	1.53E-22		
207.3	7.41E-20	554.1	3.89E-21	899.6	1.27E-22		
214.3	7.03E-20	561.2	3.70E-21	906.6	1.21E-22		
221.4	6.32E-20	566.8	3.41E-21	913.7	9.76E-23		
228.4	5.88E-20	573.9	3.32E-21	919.3	8.36E-23		
235.5	5.52E-20	580.9	3.25E-21	927.8	9.82E-23		
242.5	5.14E-20	589.4	3.00E-21	934.8	9.50E-23		
248.2	4.81E-20	595.0	2.88E-21	941.9	9.23E-23		
255.2	4.55E-20	602.1	2.58E-21	947.5	8.55E-23		
263.7	4.10E-20	609.1	2.43E-21	954.6	5.24E-23		
270.7	3.89E-20	616.2	2.29E-21	961.6	7.07E-23		
276.4	3.69E-20	623.2	2.26E-21	970.1	6.59E-23		
283.4	3.50E-20	628.9	2.06E-21	975.7	5.73E-23		
290.5	3.16E-20	637.3	1.85E-21	982.8	4.91E-23		
297.5	3.05E-20	644.4	1.82E-21	989.8	4.43E-23		

Note: The low electron energy portion in these data was taken with a time-of-flight system and, thus, should be accurate down to about 1 eV.

Reference: These data were taken from L. H. Toburen and S. T. Manson, Phys. Rev. A, to be published (1979).

Tabular Data I-2.A-14. Single differential cross section (secondary electron spectra) for H^+ + Ne collisions (units of cm^2/eV).

Electron Energy (eV)	Proton Energy 1 MeV	Proton Energy 1.5 MeV
0.0	1.34-18	1.38-18
1.0	1.52-18	1.27-18
2.0	1.41-18	1.27-18
4.0	1.24-18	1.15-15
6.0	1.11-18	1.08-18
8.0	1.04-18	9.96-19
10.0	9.66-19	9.27-19
15.0	8.04-19	7.68-19
20.0	6.99-19	6.57-19
30.0	5.26-19	4.64-19
40.0	3.94-19	3.44-19
50.0	3.03-19	2.59-19
60.0	2.39-19	2.02-19
70.0	1.93-19	1.61-19
80.0	1.58-19	1.27-19
90.0	1.32-19	1.05-19
100.0	1.09-19	8.65-20
150.0	5.26-20	3.97-20
200.0	2.97-20	2.24-20
250.0	1.89-20	1.38-20
300.0	1.29-20	9.39-21
350.0	9.38-21	6.91-21
400.0	7.06-21	4.99-21
450.0	5.39-21	3.86-21
500.0	4.30-21	3.15-21
550.0	3.50-21	2.51-21
600.0	2.87-21	2.07-21
650.0	2.40-21	1.75-21
700.0	2.07-21	1.53-21
750.0	2.21-21	2.07-21
800.0	2.46-21	2.19-21
850.0	1.65-21	1.17-21
900.0	1.10-21	7.86-22
950.0	1.07-21	7.56-22
1000.0	9.71-22	6.68-22
1100.0	7.94-22	5.54-22
1200.0	6.62-22	4.55-22
1300.0	5.58-22	4.04-22
1400.0	4.72-22	3.40-22
1500.0	3.98-22	2.98-22
1750.0	2.55-22	2.16-22
2000.0	1.30-22	1.70-22
2250.0	5.46-23	1.34-22
2500.0	1.84-23	1.03-22
2750.0	5.83-24	7.27-23
3000.0	1.36-24	4.44-23
3500.0		1.02-23

Note: The low electron energy portion in these data was taken with a time-of-flight system and, thus, should be accurate down to about 1 eV.

Reference: These data were taken from L. H. Toburen and S. T. Manson, Phys. Rev. A, to be published (1979).

Tabular Data I-2.A-15. Single differential cross section (secondary electron spectra) for H^+ + Ar collisions (units of m^2/eV).

Electron Energy (eV)	Proton Energy (keV) 5	7	10	15	20	30	50	70
1.5	2.33-21	2.48-21	2.38-21	2.36-21	2.87-21	2.77-21	2.67-21	2.62-21
2.0	2.27-21	2.19-21	2.40-21	2.49-21	3.03-21	2.86-21	2.72-21	2.67-21
3.0	1.62-21	1.90-21	2.14-21	2.38-21	2.80-21	2.64-21	2.51-21	2.46-21
5.0	9.95-22	1.27-21	1.51-21	1.88-21	2.33-21	2.24-21	2.07-21	2.07-21
7.5	6.19-22	8.94-22	1.17-21	1.54-21	1.98-21	2.01-21	1.84-21	1.85-21
10.0	3.95-22	6.19-22	8.51-22	1.17-21	1.60-21	1.75-21	1.58-21	1.60-21
15.0	3.00-22	4.20-22	5.35-22	7.43-22	9.71-22	1.28-21	1.14-21	1.21-21
20.0	7.47-23	1.33-22	2.43-22	3.74-22	5.44-22	7.60-22	8.34-22	8.82-22
30.0	1.50-23	3.36-23	7.64-23	1.56-22	2.36-22	3.75-22	5.28-22	5.18-22
50.0	5.05-24	2.69-24	8.93-24	2.66-23	5.07-23	1.14-22	2.25-22	1.87-22
75.0	1.21-24	6.69-25	1.18-24	3.57-24	8.60-24	2.87-23	9.03-23	6.61-23
100.0	2.01-25	2.01-25	4.32-25	8.75-25	1.61-24	7.05-24	4.05-23	2.47-23
130.0	2.42-25	9.57-26	1.33-25	2.39-25	2.94-25	1.32-24	1.62-23	7.28-24
160.0	1.55-25	9.34-27	4.60-26	1.03-25	9.93-26	3.34-25	6.56-24	2.07-24
200.0	1.55-26	6.75-26	2.01-26	4.11-26	5.56-26	2.11-25	2.45-24	7.35-25
250.0	* * *	4.51-27	1.89-26	1.38-26	3.11-27	3.03-26	3.16-25	4.29-26
300.0	3.70-26	* * *	4.07-28	* * *	* * *	5.99-27	8.16-26	7.48-27

Reference: These data were taken from T. L. Criswell, L. H. Toburen, and M. E. Rudd, Phys. Rev. A 16, 508.

AD-A073 575 ARMY MISSILE RESEARCH AND DEVELOPMENT COMMAND REDSTO--ETC F/G 20/5
COMPILATION OF DATA RELEVANT TO NUCLEAR PUMPED LASERS. VOLUME V--ETC(U)
FEB 79 E W MCDANIEL, M R FLANNERY, E W THOMAS

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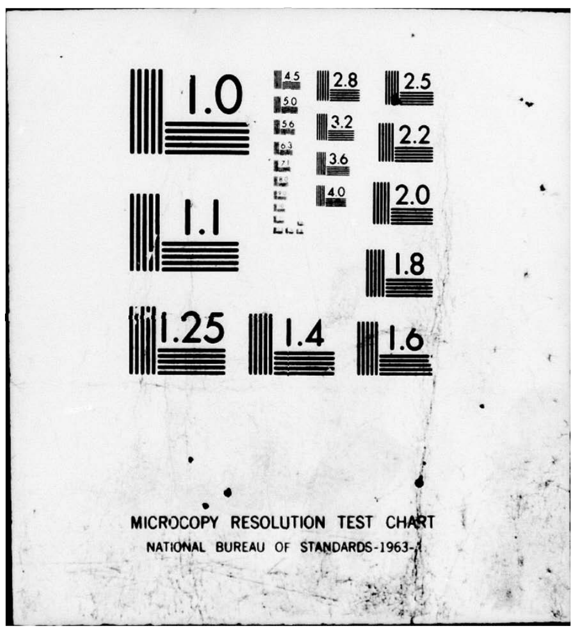
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Tabular Data I-2.A-16. Single differential cross section (secondary electron spectra) for H^+ + Ar collisions (units of cm^2/eV).

ELECTRON ENERGY (EV)	Proton Energy (keV) 50	100	150	200	250	300
0.0	2.463E-17	2.189E-17	1.670E-17	1.328E-17	1.213E-17	1.045E-17
1.49	2.341E-17	2.134E-17	1.760E-17	1.448E-17	1.310E-17	1.131E-17
3.41	2.250E-17	2.121E-17	1.900E-17	1.629E-17	1.450E-17	1.263E-17
5.34	2.006E-17	1.872E-17	1.739E-17	1.536E-17	1.369E-17	1.225E-17
7.26	1.716E-17	1.655E-17	1.532E-17	1.384E-17	1.243E-17	1.121E-17
9.18	1.542E-17	1.484E-17	1.373E-17	1.263E-17	1.123E-17	1.017E-17
11.11	1.484E-17	1.403E-17	1.278E-17	1.168E-17	1.040E-17	9.317E-18
13.03	1.307E-17	1.178E-17	1.055E-17	9.758E-18	8.380E-18	7.643E-18
17.15	1.045E-17	8.887E-18	7.513E-18	6.607E-18	5.713E-18	5.048E-18
21.27	8.044E-18	6.670E-18	5.459E-18	4.631E-18	3.912E-18	3.384E-18
25.40	6.506E-18	5.363E-18	4.246E-18	3.487E-18	2.887E-18	2.464E-18
29.52	5.020E-18	4.518E-18	3.521E-18	2.834E-18	2.327E-18	1.962E-18
33.64	4.060E-18	3.948E-18	3.022E-18	2.404E-18	1.963E-18	1.644E-18
37.76	3.413E-18	3.492E-18	2.640E-18	2.072E-18	1.675E-18	1.396E-18
47.38	2.204E-18	2.623E-18	1.984E-18	1.528E-18	1.222E-18	1.016E-18
57.00	1.432E-18	1.890E-18	1.518E-18	1.157E-18	9.208E-19	7.622E-19
66.62	9.600E-19	1.378E-18	1.213E-18	9.250E-19	7.331E-19	6.035E-19
76.23	6.475E-19	1.038E-18	9.729E-19	7.642E-19	6.005E-19	4.945E-19
85.85	4.379E-19	7.940E-19	7.743E-19	6.393E-19	5.039E-19	4.120E-19
95.47	2.951E-19	6.276E-19	6.257E-19	5.381E-19	4.272E-19	3.486E-19
109.21	1.670E-19	4.487E-19	4.665E-19	4.206E-19	3.418E-19	2.819E-19
122.95	9.259E-20	3.246E-19	3.587E-19	3.265E-19	2.778E-19	2.305E-19
136.69	5.111E-20	2.351E-19	2.795E-19	2.603E-19	2.284E-19	1.946E-19
150.43	2.903E-20	1.728E-19	2.232E-19	2.148E-19	1.909E-19	1.670E-19
164.17	1.741E-20	1.298E-19	1.863E-19	1.849E-19	1.662E-19	1.503E-19
177.91	1.220E-20	1.005E-19	1.595E-19	1.669E-19	1.571E-19	1.466E-19
191.65	1.105E-20	8.587E-20	1.494E-19	1.668E-19	1.638E-19	1.598E-19
205.39	5.659E-21	6.121E-20	1.227E-19	1.510E-19	1.548E-19	1.572E-19
219.13	1.079E-21	3.239E-20	7.482E-20	8.668E-20	8.024E-20	7.068E-20
232.87	1.177E-21	2.198E-20	5.842E-20	7.204E-20	6.837E-20	6.042E-20
246.61	7.457E-22	1.496E-20	4.629E-20	6.110E-20	5.919E-20	5.197E-20
260.35	5.571E-22	1.028E-20	3.699E-20	5.139E-20	5.250E-20	4.676E-20
274.09	4.324E-22	7.174E-21	2.947E-20	4.424E-20	4.601E-20	4.171E-20
287.83	3.695E-22	4.662E-21	2.322E-20	3.765E-20	4.076E-20	3.705E-20
342.79	1.591E-22	1.675E-21	8.114E-21	1.944E-20	2.480E-20	2.464E-20
397.75	9.897E-23	3.117E-22	2.540E-21	9.394E-21	1.484E-20	1.664E-20
452.71	5.220E-23	1.471E-22	8.116E-22	3.998E-21	8.490E-21	1.069E-20
507.67	3.390E-23	7.521E-23	3.062E-22	1.572E-21	4.493E-21	6.959E-21
562.63	2.211E-23	5.577E-23	1.374E-22	6.546E-22	2.173E-21	4.317E-21
617.59	1.962E-23	2.814E-23	7.456E-23	2.677E-22	1.038E-21	2.479E-21
727.51	7.601E-24	9.390E-24	3.317E-23	7.890E-23	2.295E-22	7.146E-22
837.43	3.070E-24	4.951E-24	1.403E-23	3.799E-23	7.732E-23	1.938E-22
947.35	8.223E-24	7.224E-25	7.917E-24	2.045E-23	3.045E-23	6.431E-23
1057.27	6.415E-24	4.056E-24	2.191E-24	1.147E-23	1.785E-23	2.959E-23

Reference: These data were taken from J. B. Crooks and M. E. Rudd, Phys. Rev. A 3, 1628 (1974).

Tabular Data I-2.A-17. Single differential cross section (secondary electron spectra) for H^+ + Ar collisions (units of cm^2/eV).

E(EV)	Proton Energy 300 keV	400 keV	500 keV
1.166	0.2434E-16	0.1415E-16	0.1074E-16
1.359	0.2459E-16	0.1354E-16	0.1098E-16
1.585	0.2394E-16	0.1262E-16	0.1071E-16
1.848	0.2229E-16	0.1192E-16	0.1023E-16
2.154	0.2078E-16	0.1114E-16	0.9258E-17
2.512	0.1922E-16	0.1042E-16	0.8393E-17
2.929	0.1883E-16	0.9386E-17	0.7511E-17
3.415	0.1714E-16	0.8092E-17	0.6578E-17
3.981	0.1623E-16	0.6596E-17	0.5515E-17
4.642	0.1522E-16	0.5180E-17	0.4417E-17
5.412	0.1415E-16	0.3889E-17	0.3282E-17
6.313	0.1306E-16	0.2906E-17	0.2437E-17
7.356	0.1195E-16	0.2166E-17	0.1748E-17
8.577	0.1094E-16	0.1669E-17	0.1314E-17
10.00	0.9402E-17	0.1318E-17	0.1028E-17
11.66	0.8125E-17	0.1256E-17	0.8144E-18
13.59	0.6482E-17	0.8434E-18	0.6459E-18
15.85	0.5475E-17	0.6692E-18	0.5137E-18
18.48	0.3894E-17	0.5239E-18	0.4013E-18
21.54	0.2999E-17	0.4092E-18	0.3284E-18
25.12	0.2315E-17	0.3209E-18	0.2404E-18
29.29	0.1819E-17	0.2513E-18	0.1883E-18
34.15	0.1448E-17	0.1954E-18	0.1452E-18
39.81	0.1157E-17	0.1628E-19	0.1217E-18
46.42	0.9181E-18	0.1320E-18	0.9882E-19
54.12	0.7252E-18	0.1033E-18	0.7846E-19
63.10	0.5691E-18	0.7702E-19	0.5569E-19
73.56	0.4446E-18	0.5416E-19	0.3781E-19
85.77	0.3478E-18	0.3598E-19	0.2339E-19
100.0	0.2711E-18	0.2673E-19	0.1724E-19
116.6	0.2126E-18	0.1940E-19	0.1253E-19
135.9	0.1819E-18	0.1414E-19	0.9188E-20
158.5	0.1472E-18	0.9877E-20	0.6844E-20
194.8	0.1153E-18	0.6322E-20	0.5007E-20
215.4	0.8322E-19	0.3479E-20	0.3402E-20
251.2	0.5557E-19	0.1549E-20	0.1977E-20
292.9	0.3455E-19	0.5109E-21	0.9458E-21
341.5	0.2514E-19	0.1213E-21	0.3318E-21
398.1	0.1695E-19	0.3215E-22	0.6036E-22
464.2	0.1036E-19		
541.2	0.5538E-20		
631.0	0.2507E-20		
735.6	0.9626E-21		
857.7			
1000.			
1166.			
1359.			

Reference: These data were taken from H. Gabler, Thesis (Free University of Berlin, 1974), unpublished.

Tabular Data I-2.A-18. Single differential cross section (secondary electron spectra) for H^+ + Ar collisions (units of cm^2/eV).

ENERGY (EV)	Proton Energy= 0.5 MeV
0.0	8.73-18
1.0	1.07-17
2.0	1.10-17
4.0	1.04-17
6.0	9.59-18
8.0	8.12-18
10.0	7.67-18
15.0	5.10-18
25.0	1.78-18
50.0	5.83-19
75.0	3.15-19
100.0	2.03-19
150.0	1.13-19
200.0	1.73-19
300.0	2.56-20
400.0	1.38-20
500.0	8.12-21
750.0	3.00-21
1000.0	8.88-22
1250.0	1.13-22
1500.0	1.52-23
1750.0	4.05-24
2000.0	2.20-26

ENERGY (EV)	Proton Energy = 1 MeV	1.5 MeV
0.0	5.91-18	5.04-18
1.0	6.92-18	5.04-18
2.0	6.54-18	5.14-18
4.0	6.02-18	4.91-18
6.0	5.29-18	4.50-18
8.0	4.82-18	4.15-18
10.0	4.42-18	3.74-18
15.0	2.70-18	2.10-18
20.0	1.39-18	1.04-18
30.0	5.95-19	4.54-19
40.0	3.82-19	3.00-19
50.0	2.85-19	2.19-19
60.0	2.23-19	1.73-19
70.0	1.78-19	1.33-19
80.0	1.47-19	1.13-19
90.0	1.27-19	9.66-20
100.0	1.03-19	8.14-20
150.0	6.30-20	5.15-20
200.0	1.45-19	1.32-19
250.0	2.16-20	1.63-20
300.0	1.54-20	1.15-20
350.0	1.16-20	8.75-21
400.0	9.04-21	6.63-21
450.0	7.19-21	5.42-21
500.0	5.86-21	4.47-21
550.0	4.83-21	3.64-21
600.0	3.95-21	3.09-21
650.0	3.41-21	2.61-21
700.0	2.90-21	2.18-21
750.0	2.44-21	1.83-21
800.0	2.12-21	1.58-21
850.0	1.88-21	1.40-21
900.0	1.65-21	1.26-21
950.0	1.46-21	1.12-21
1000.0	1.30-21	1.01-21
1100.0	1.08-21	8.15-22
1200.0	9.11-22	6.99-22
1300.0	7.49-22	5.78-22
1400.0	6.49-22	4.99-22
1500.0	5.60-22	4.39-22
1750.0	3.88-22	3.22-22
2000.0	2.10-22	2.43-22
2250.0	8.06-23	1.93-22
2500.0	2.14-23	1.51-22
2750.0	6.87-24	1.18-22
3000.0	3.10-24	7.32-23
3500.0	2.68-25	1.29-23

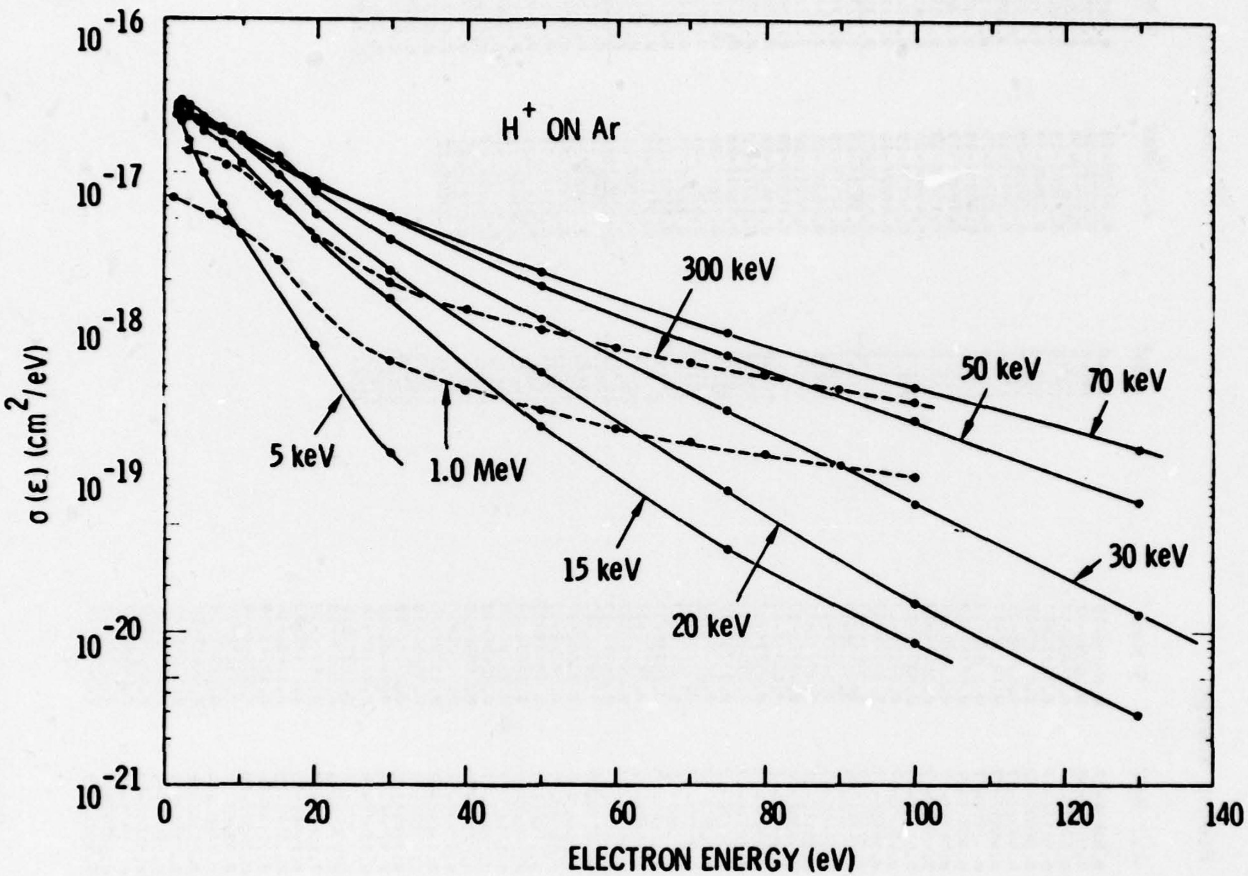
Reference: These data were taken from T. L. Criswell, L. H. Toburen, and M. E. Rudd, Phys. Rev. A 16, 508.

Tabular Data I-2.A-19. Single differential cross section (secondary electron spectra) for H^+ + Ar collisions (units of cm^2/eV).

	Proton Energy	
E(EV)	4.2 MeV	5 MeV
1.000	0.5143E-17	0.8485E-17
1.166	0.5236E-17	0.8353E-17
1.259	0.5293E-17	0.7663E-17
1.359	0.5215E-17	0.7291E-17
1.468	0.5068E-17	0.6878E-17
1.585	0.4850E-17	0.6608E-17
1.711	0.4694E-17	0.6322E-17
1.848	0.4579E-17	0.5997E-17
1.995	0.4501E-17	0.5764E-17
2.154	0.4454E-17	0.5582E-17
2.326	0.4327E-17	0.5512E-17
2.512	0.4133E-17	0.5380E-17
2.712	0.4007E-17	0.5315E-17
2.929	0.3865E-17	0.5410E-17
3.162	0.3757E-17	0.5480E-17
3.415	0.3642E-17	0.5420E-17
3.687	0.3549E-17	0.5277E-17
3.981	0.3511E-17	0.4973E-17
4.299	0.3535E-17	0.4675E-17
4.642	0.3552E-17	0.4493E-17
5.012	0.3599E-17	0.4327E-17
5.412	0.3667E-17	0.4108E-17
5.843	0.3712E-17	0.3873E-17
6.310	0.3697E-17	0.3609E-17
6.813	0.3585E-17	0.3323E-17
7.356	0.3385E-17	0.3091E-17
7.943	0.3266E-17	0.2923E-17
8.577	0.3067E-17	0.2630E-17
9.261	0.2924E-17	0.2408E-17
10.00	0.2571E-17	0.2174E-17
10.80	0.2346E-17	0.1950E-17
11.66	0.2085E-17	0.1768E-17
12.59	0.1872E-17	0.1600E-17
13.59	0.1666E-17	0.1346E-17
14.68	0.1434E-17	0.1169E-17
15.85	0.1216E-17	0.9970E-18
17.11	0.1023E-17	0.8248E-18
18.48	0.8411E-18	0.6888E-18
19.95	0.6920E-18	0.5650E-18
21.54	0.5384E-18	0.4538E-18
23.26	0.4312E-18	0.3665E-18
25.12	0.3441E-18	0.2978E-18
27.12	0.2798E-18	0.2442E-18
29.29	0.2396E-18	0.2031E-18
31.62	0.2082E-18	0.1795E-18
34.15	0.1798E-18	0.1603E-18
36.87	0.1568E-18	0.1455E-18
39.81	0.1446E-18	0.1330E-18
42.99	0.1314E-18	0.1206E-18
46.42	0.1174E-18	0.1051E-18
50.12	0.1051E-18	0.9027E-19
54.12	0.9206E-19	0.7925E-19
58.43	0.7962E-19	0.7228E-19
63.10	0.7330E-19	0.6441E-19
68.13	0.6571E-19	0.5929E-19
73.56	0.5755E-19	0.5557E-19
79.43	0.5168E-19	0.5036E-19
85.77	0.4630E-19	0.4496E-19
92.61	0.4029E-19	0.3978E-19
100.0	0.3586E-19	0.3274E-19

	Proton Energy	
E(EV)	4.2 MeV	5 MeV
100.0	0.3229E-19	0.2853E-19
116.6	0.2873E-19	0.2551E-19
125.9	0.2596E-19	0.2206E-19
135.9	0.2388E-19	0.2008E-19
146.8	0.2240E-19	0.1949E-19
158.5	0.2059E-19	0.1397E-19
171.1	0.2841E-19	0.3580E-19
184.8	0.2970E-19	0.4411E-19
199.5	0.2586E-19	0.4069E-19
215.4	0.1985E-19	0.2967E-19
232.6	0.1123E-19	0.1516E-19
251.2	0.4564E-20	0.1833E-20
271.2	0.5623E-20	0.4767E-20
292.9	0.4822E-20	0.4115E-20
316.2	0.4373E-20	0.3319E-20
341.5	0.3531E-20	0.2777E-20
368.7	0.3046E-20	0.2399E-20
398.1	0.2570E-20	0.1972E-20
429.9	0.2221E-20	0.1719E-20
464.2	0.1858E-20	0.1504E-20
501.2	0.1543E-20	0.1269E-20
541.2	0.1337E-20	0.1099E-20
584.3	0.1181E-20	0.9469E-21
631.0	0.1001E-20	0.7913E-21
681.3	0.8789E-21	0.6501E-21
735.6	0.7725E-21	0.5274E-21
794.3	0.6590E-21	0.4271E-21
857.7	0.5712E-21	0.3661E-21
926.1	0.5150E-21	0.3278E-21
1000.	0.4507E-21	0.2981E-21
1080.	0.4008E-21	0.2678E-21
1166.	0.3576E-21	0.2356E-21
1259.	0.3085E-21	0.2083E-21
1359.	0.2570E-21	0.1756E-21
1468.	0.2147E-21	0.1496E-21
1585.	0.1766E-21	0.1223E-21
1711.	0.1442E-21	0.9813E-22
1848.	0.1178E-21	0.8099E-22
1995.	0.9723E-22	0.6799E-22
2154.	0.8318E-22	0.6120E-22
2326.		0.5727E-22
2512.		0.5220E-22
2712.		0.4359E-22
2929.		0.3565E-22
3162.		0.3286E-22

Reference: These data were taken from H. Gabler, Thesis (Free University of Berlin, 1974), unpublished.



Graphical Data I-2.A-20. Single differential cross section (secondary electron spectrum) for H^+ + Ar collisions. These data were taken from T. L. Chriswell, L. H. Toburen, and M. E. Rudd, Phys. Rev. A 16, 508 (1977).

Tabular Data I-2.A-21. Single differential cross section (secondary electron spectra) for H^+ + Xe collisions (units of cm^2/eV).

Proton Energy = 300 keV

ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)
3.	6.314-17	5.	4.582-17	7.	3.742-17	9.	2.856-17	10.	2.177-17	12.	1.635-17
14.	1.401-17	16.	1.040-17	18.	7.638-18	20.	6.733-18	21.	6.014-18	23.	5.495-18
25.	5.579-18	27.	5.092-18	29.	5.225-18	31.	5.647-18	32.	5.465-18	34.	4.370-18
36.	3.333-18	38.	3.168-18	40.	3.060-18	42.	2.958-18	43.	2.741-18	45.	2.520-18
47.	2.500-18	49.	2.332-18	51.	2.151-18	53.	2.094-18	54.	2.053-18	56.	1.810-18
58.	1.610-18	60.	1.550-18	62.	1.395-18	64.	1.364-18	65.	1.286-18	67.	1.182-18
69.	1.112-18	71.	1.091-18	73.	1.021-18	75.	9.722-19	76.	9.515-19	78.	9.022-19
80.	9.036-19	82.	8.735-19	84.	8.326-19	86.	7.777-19	87.	7.477-19	89.	7.424-19
91.	7.141-19	93.	7.134-19	95.	6.649-19	97.	6.362-19	98.	6.082-19	100.	5.940-19
102.	5.931-19	104.	5.752-19	106.	5.603-19	108.	5.716-19	109.	5.174-19	111.	5.415-19
113.	5.336-19	115.	4.692-19	117.	4.565-19	119.	4.695-19	121.	4.646-19	122.	4.565-19
124.	4.492-19	126.	4.105-19	128.	4.140-19	130.	3.984-19	132.	3.743-19	133.	3.565-19
135.	3.589-19	137.	3.474-19	139.	3.490-19	141.	3.486-19	143.	3.411-19	144.	3.133-19
146.	3.097-19	148.	3.004-19	150.	2.987-19	152.	2.942-19	154.	2.802-19	155.	2.851-19
157.	2.677-19	159.	2.720-19	161.	2.640-19	163.	2.697-19	165.	2.523-19	166.	2.490-19
168.	2.480-19	170.	2.351-19	172.	2.290-19	174.	2.239-19	176.	2.311-19	177.	2.169-19
179.	2.140-19	181.	2.123-19	183.	2.086-19	185.	2.033-19	187.	1.901-19	188.	1.936-19
190.	1.918-19	192.	1.921-19	194.	1.786-19	196.	1.777-19	198.	1.765-19	199.	1.688-19
201.	1.633-19	203.	1.734-19	205.	1.619-19	207.	1.553-19	209.	1.565-19	210.	1.560-19
212.	1.546-19	214.	1.504-19	216.	1.420-19	218.	1.424-19	220.	1.436-19	221.	1.421-19
223.	1.338-19	225.	1.393-19	227.	1.329-19	229.	1.323-19	231.	1.300-19	232.	1.284-19
234.	1.178-19	236.	1.197-19	238.	1.220-19	240.	1.153-19	242.	1.195-19	244.	1.144-19
245.	1.091-19	247.	1.077-19	249.	1.106-19	251.	1.127-19	253.	1.057-19	255.	9.986-20
256.	9.823-20	258.	9.698-20	260.	1.037-19	262.	9.768-20	264.	9.371-20	266.	9.416-20
267.	8.864-20	269.	9.139-20	271.	9.133-20	273.	8.667-20	275.	8.486-20	277.	8.573-20
278.	8.302-20	280.	8.315-20	282.	8.373-20	284.	8.129-20	286.	7.920-20	288.	7.150-20
289.	7.799-20	291.	7.623-20	293.	7.284-20	295.	7.148-20	297.	7.548-20	299.	7.399-20
300.	7.092-20	302.	7.161-20	304.	6.816-20	306.	6.826-20	308.	6.946-20	310.	6.773-20
311.	6.093-20	313.	6.184-20	315.	6.402-20	317.	6.408-20	319.	6.479-20	321.	5.809-20
322.	6.080-20	324.	6.158-20	326.	5.770-20	328.	5.577-20	330.	5.413-20	332.	5.753-20
333.	5.849-20	335.	5.796-20	337.	5.486-20	339.	5.050-20	341.	5.230-20	343.	5.242-20
344.	5.355-20	346.	5.065-20	348.	5.124-20	350.	4.984-20	352.	5.037-20	354.	4.774-20
356.	4.819-20	357.	4.891-20	359.	4.668-20	361.	4.577-20	363.	4.724-20	365.	4.936-20
367.	4.189-20	368.	4.305-20	370.	3.999-20	372.	3.981-20	374.	4.071-20	376.	4.008-20
378.	4.067-20	381.	3.784-20	387.	3.798-20	392.	3.580-20	398.	3.426-20	403.	3.247-20
409.	3.299-20	414.	3.233-20	420.	3.084-20	425.	2.925-20	431.	2.700-20	436.	2.660-20
442.	2.530-20	447.	2.561-20	455.	2.326-20	464.	2.202-20	473.	2.075-20	482.	1.997-20
491.	1.807-20	501.	1.674-20	510.	2.312-20	519.	1.408-20				

ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)
528.	1.319-20	537.	1.139-20	546.	1.017-20	556.	9.600-21	565.	8.958-21	574.	8.336-21
583.	7.832-21	592.	6.866-21	602.	6.200-21	611.	5.670-21	620.	5.242-21	629.	4.849-21
638.	4.039-21	647.	3.723-21	657.	3.160-21	666.	3.045-21	675.	2.433-21	686.	2.203-21
699.	1.959-21	712.	1.685-21	725.	1.418-21	737.	1.172-21	750.	1.017-21	763.	8.257-22
776.	7.011-22	789.	6.644-22	802.	5.713-22	815.	3.643-22	827.	3.122-22	840.	2.496-22
853.	2.268-22	866.	2.141-22	879.	2.033-22	892.	1.735-22	906.	1.561-22	923.	1.249-22
939.	1.206-22	956.	9.548-23	972.	7.897-23	989.	3.997-23				

Note: Energy is secondary electron energy in eV.

Reference: These data were taken from L. H. Touburen, Phys. Rev. A 9, 2505 (1974).

Tabular Data I-2.A-22. Single differential cross section (secondary electron spectra) for H^+ + Xe collisions (units of cm^2/eV).

Proton Energy = 1.0 MeV

ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)
0.	5.000-17	4.	3.676-17	8.	1.625-17	12.	8.372-18	16.	4.850-18	20.	3.023-18
24.	2.378-18	27.	2.575-18	31.	2.863-18	35.	1.713-18	39.	1.299-18	43.	1.132-18
47.	1.011-18	51.	9.501-19	55.	7.989-19	59.	6.507-19	63.	5.702-19	67.	4.995-19
71.	4.390-19	75.	3.869-19	79.	3.539-19	82.	3.277-19	86.	3.001-19	90.	2.836-19
94.	2.673-19	98.	2.464-19	102.	2.319-19	106.	2.259-19	110.	2.105-19	114.	1.933-19
118.	1.865-19	122.	1.762-19	126.	1.675-19	130.	1.492-19	134.	1.477-19	137.	1.400-19
141.	1.331-19	145.	1.281-19	149.	1.223-19	153.	1.159-19	157.	1.131-19	161.	1.070-19
165.	1.049-19	169.	1.012-19	173.	9.714-20	177.	9.456-20	181.	9.300-20	185.	8.862-20
189.	8.533-20	192.	8.253-20	196.	8.220-20	200.	7.874-20	204.	7.479-20	208.	7.277-20
212.	7.229-20	216.	6.955-20	220.	6.605-20	224.	6.616-20	228.	6.501-20	232.	6.223-20
236.	6.206-20	240.	5.915-20	244.	5.616-20	247.	5.531-20	251.	5.489-20	255.	5.350-20
259.	4.962-20	263.	5.113-20	267.	5.015-20	271.	4.761-20	275.	4.782-20	279.	4.492-20
283.	4.559-20	287.	4.480-20	291.	4.361-20	295.	4.238-20	299.	3.979-20	302.	3.932-20
306.	4.095-20	310.	3.869-20	314.	3.871-20	318.	3.754-20	322.	3.657-20	326.	3.492-20
330.	3.416-20	334.	3.478-20	338.	3.334-20	342.	3.331-20	346.	3.377-20	350.	3.255-20
354.	3.141-20	357.	3.135-20	361.	2.863-20	365.	2.911-20	369.	2.962-20	373.	2.999-20
377.	2.810-20	381.	2.787-20	385.	2.747-20	389.	2.630-20	393.	2.591-20	397.	2.531-20
401.	2.520-20	405.	2.560-20	409.	2.452-20	412.	2.393-20	416.	2.409-20	420.	2.341-20
424.	2.310-20	428.	2.210-20	432.	2.174-20	436.	2.243-20	440.	2.170-20	444.	2.121-20
448.	1.967-20	452.	1.981-20	456.	1.929-20	460.	1.864-20	464.	1.796-20	467.	1.755-20
471.	1.784-20	475.	1.749-20	479.	1.770-20	483.	1.867-20	487.	1.794-20	491.	1.737-20
495.	1.815-20	499.	1.663-20	503.	1.887-20	507.	1.907-20	511.	1.964-20	515.	1.926-20
519.	1.942-20	522.	1.974-20	526.	1.840-20	530.	1.754-20	534.	1.576-20	538.	1.474-20
542.	1.385-20	546.	1.264-20	550.	1.169-20	554.	1.173-20	558.	1.146-20	562.	1.101-20
566.	1.096-20	570.	1.130-20	574.	1.073-20	577.	1.054-20	581.	1.081-20	585.	1.060-20
589.	1.012-20	593.	9.528-21	597.	9.445-21	601.	9.529-21	605.	9.068-21	609.	9.065-21
613.	9.201-21	617.	8.542-21	621.	8.845-21	625.	8.285-21	629.	8.085-21	632.	7.999-21
636.	8.037-21	640.	8.247-21	644.	7.640-21	648.	7.797-21	652.	7.982-21	656.	7.500-21
660.	7.464-21	664.	7.542-21	668.	7.309-21	672.	7.454-21	676.	7.204-21	680.	7.468-21
684.	7.304-21	687.	7.289-21	691.	7.213-21	695.	7.229-21	699.	6.763-21	703.	7.030-21
707.	6.729-21	711.	6.340-21	715.	6.743-21	719.	6.421-21	723.	6.637-21	727.	6.309-21
731.	6.298-21	735.	6.300-21	739.	6.497-21	742.	6.076-21	746.	6.012-21	750.	6.114-21
754.	5.726-21	758.	5.991-21	762.	5.773-21	766.	5.697-21	770.	5.593-21	774.	5.490-21
778.	5.430-21	782.	5.500-21	786.	5.334-21	790.	5.565-21	794.	5.334-21	797.	5.400-21
801.	5.240-21	813.	5.199-21	833.	4.873-21	852.	4.640-21	872.	4.355-21	892.	4.238-21
915.	3.866-21	943.	3.655-21	970.	3.834-21	998.	3.131-21	1025.	2.917-21	1053.	2.739-21
1080.	2.527-21	1108.	2.366-21	1135.	2.230-21	1163.	2.112-21	1190.	1.946-21	1222.	1.779-21
1257.	1.643-21	1292.	1.485-21	1328.	1.401-21	1363.	1.304-21	1399.	1.190-21	1434.	1.112-21
1469.	1.057-21	1505.	9.377-22	1544.	8.991-22	1587.	8.180-22	1630.	7.494-22	1674.	6.957-22
1717.	6.717-22	1760.	6.089-22	1803.	5.505-22	1850.	4.859-22	1901.	4.287-22	1952.	3.473-22
2004.	2.915-22	2055.	2.556-22	2106.	2.024-22	2161.	1.566-22	2220.	1.259-22	2279.	9.838-23
2337.	7.780-23	2396.	5.917-23	2459.	4.789-23	2526.	1.178-22	2593.	2.938-23	2660.	2.174-23

Note: Energy is secondary electron energy in eV.

Reference: These data were taken from L. H. Toburen, Phys. Rev. A 9, 2505 (1974).

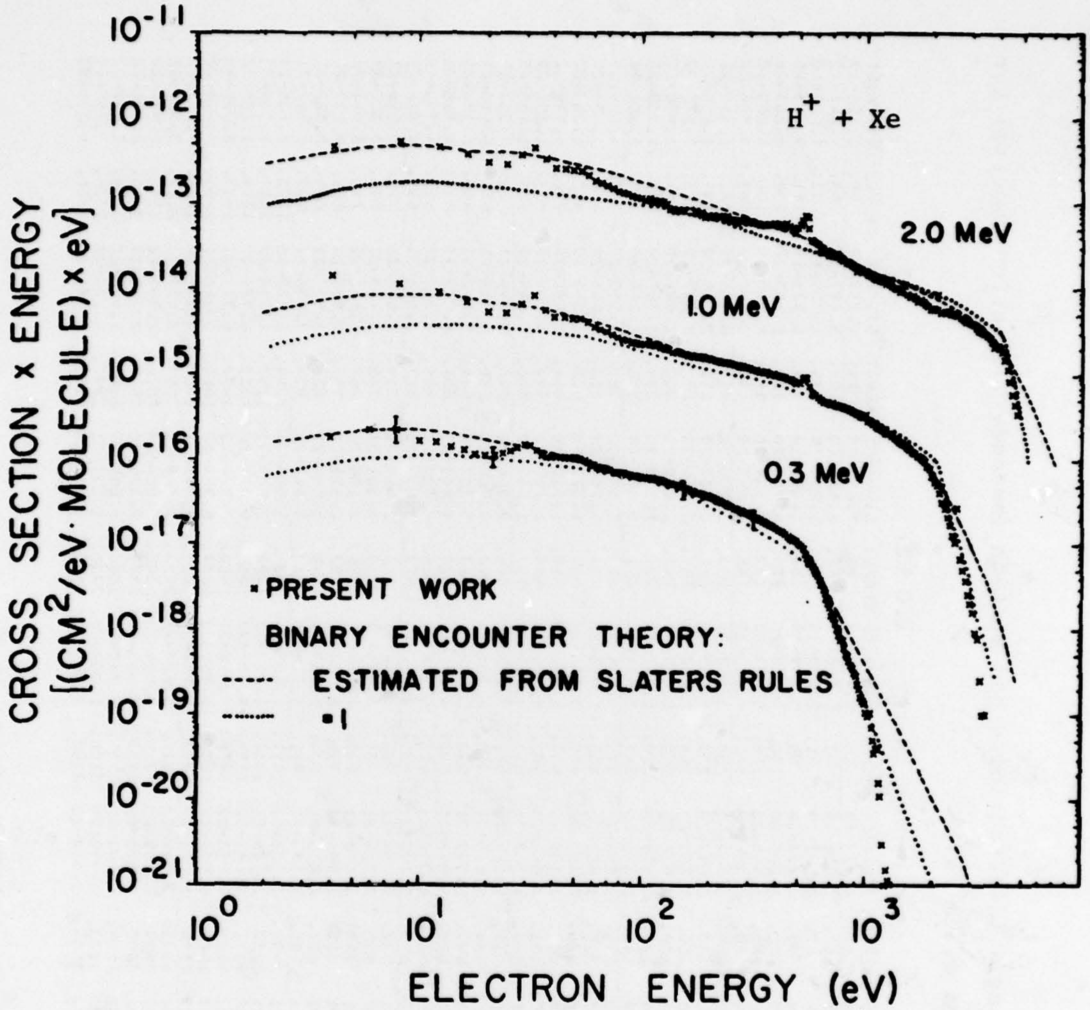
Tabular Data I-2.A-23. Single differential cross section (secondary electron spectra) for H^+ + Xe collisions (units of cm^2/eV).

Proton Energy = 2.0 MeV

ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)
4.	7.313-18	8.	6.513-18	12.	4.120-18	16.	2.757-18	20.	1.654-18	24.	1.237-18	28.	1.226-18
32.	1.634-18	36.	1.106-18	40.	7.011-19	43.	6.200-19	47.	5.466-19	51.	5.127-19	55.	4.342-19
59.	3.435-19	63.	2.890-19	67.	2.523-19	71.	2.239-19	75.	1.972-19	79.	1.759-19	83.	1.627-19
87.	1.532-19	91.	1.359-19	95.	1.298-19	99.	1.197-19	103.	1.099-19	107.	1.029-19	111.	9.683-20
114.	9.316-20	118.	8.662-20	122.	8.269-20	126.	7.421-20	130.	6.936-20	134.	6.617-20	138.	6.263-20
142.	6.069-20	146.	5.649-20	150.	5.499-20	154.	5.279-20	158.	5.139-20	162.	4.910-20	166.	4.663-20
170.	4.605-20	174.	4.566-20	178.	4.386-20	182.	4.180-20	185.	4.057-20	189.	3.847-20	193.	3.700-20
197.	3.583-20	201.	3.422-20	205.	3.503-20	209.	3.398-20	213.	3.275-20	217.	3.135-20	221.	3.109-20
225.	3.000-20	229.	2.965-20	233.	2.857-20	237.	2.817-20	241.	2.733-20	245.	2.669-20	249.	2.616-20
253.	2.398-20	257.	2.466-20	260.	2.354-20	264.	2.300-20	268.	2.254-20	272.	2.185-20	276.	2.171-20
280.	2.095-20	284.	2.099-20	288.	2.012-20	292.	2.097-20	296.	1.980-20	300.	1.944-20	304.	1.880-20
308.	1.868-20	312.	1.847-20	316.	1.854-20	320.	1.791-20	324.	1.830-20	328.	1.760-20	331.	1.739-20
335.	1.663-20	339.	1.675-20	343.	1.643-20	347.	1.674-20	351.	1.662-20	355.	1.590-20	359.	1.602-20
363.	1.564-20	367.	1.549-20	371.	1.511-20	375.	1.504-20	379.	1.591-20	383.	1.553-20	387.	1.529-20
391.	1.503-20	395.	1.450-20	399.	1.452-20	403.	1.455-20	406.	1.503-20	410.	1.456-20	414.	1.455-20
418.	1.443-20	422.	1.446-20	426.	1.363-20	430.	1.380-20	434.	1.372-20	438.	1.349-20	442.	1.359-20
446.	1.328-20	450.	1.278-20	454.	1.195-20	458.	1.060-20	462.	1.072-20	466.	1.004-20	470.	9.949-21
474.	1.011-20	477.	1.018-20	481.	1.066-20	485.	1.131-20	489.	1.110-20	493.	1.168-20	497.	1.201-20
501.	1.255-20	505.	1.288-20	509.	1.360-20	513.	1.411-20	517.	1.487-20	521.	1.649-20	525.	1.736-20
529.	1.695-20	533.	1.468-20	537.	1.262-20	541.	1.073-20	545.	9.094-21	548.	7.894-21	552.	7.357-21
556.	6.997-21	560.	6.937-21	564.	6.475-21	568.	6.731-21	572.	6.766-21	576.	6.512-21	580.	6.610-21
584.	6.666-21	588.	6.397-21	592.	6.549-21	596.	5.962-21	600.	5.722-21	604.	5.642-21	608.	5.324-21
612.	5.073-21	616.	5.188-21	620.	4.848-21	623.	4.672-21	627.	4.711-21	631.	4.734-21	635.	4.395-21
639.	4.629-21	643.	4.456-21	647.	4.303-21	651.	4.418-21	655.	4.331-21	659.	4.366-21	663.	[illegible]
667.	4.289-21	671.	4.051-21	675.	4.199-21	679.	3.940-21	683.	3.975-21	687.	3.964-21	691.	4.016-21
694.	3.841-21	698.	3.922-21	702.	3.764-21	706.	3.784-21	710.	3.664-21	714.	3.673-21	718.	3.846-21
722.	3.660-21	726.	3.718-21	730.	3.514-21	734.	3.515-21	738.	3.531-21	742.	3.440-21	746.	3.309-21
750.	3.207-21	754.	3.301-21	758.	3.193-21	762.	3.395-21	766.	3.190-21	769.	3.111-21	773.	3.041-21
777.	3.065-21	781.	3.074-21	785.	2.990-21	789.	2.980-21	793.	2.874-21	797.	2.852-21	801.	2.837-21
805.	2.733-21	809.	2.709-21	817.	2.683-21	829.	2.637-21	840.	2.599-21	852.	2.537-21	864.	2.392-21
876.	2.309-21	888.	2.265-21	900.	2.139-21	911.	2.134-21	923.	2.043-21	935.	2.046-21	947.	1.945-21
959.	1.947-21	975.	1.854-21	994.	1.733-21	1014.	1.683-21	1034.	1.603-21	1054.	1.522-21	1073.	1.439-21
1093.	1.367-21	1113.	1.367-21	1132.	1.275-21	1152.	1.222-21	1172.	1.185-21	1192.	1.149-21	1211.	1.091-21
1231.	9.917-22	1251.	9.701-22	1271.	9.641-22	1290.	9.152-22	1310.	9.024-22	1330.	6.781-22	1349.	8.286-22
1369.	8.308-22	1389.	7.998-22	1409.	7.733-22	1428.	7.342-22	1448.	7.424-22	1472.	6.724-22	1499.	6.606-22
1527.	6.433-22	1555.	6.147-22	1582.	5.907-22	1610.	5.751-22	1637.	5.754-22	1665.	5.445-22	1693.	5.440-22
1720.	5.156-22	1748.	5.037-22	1776.	5.093-22	1803.	4.570-22	1831.	4.492-22	1858.	4.270-22	1886.	4.071-22
1914.	3.968-22	1945.	3.877-22	1981.	3.756-22	2016.	3.620-22	2052.	3.540-22	2087.	3.477-22	2123.	3.369-22
2158.	3.288-22	2194.	3.211-22	2229.	3.142-22	2265.	3.094-22	2300.	3.086-22	2336.	2.985-22	2371.	2.896-22
2407.	2.822-22	2446.	2.683-22	2490.	2.570-22	2533.	2.469-22	2577.	2.337-22	2620.	2.249-22	2663.	2.121-22
2707.	1.936-22	2750.	1.853-22	2794.	1.792-22	2837.	1.745-22	2880.	1.699-22	2928.	1.653-22	2979.	1.621-22
3030.	1.562-22	3082.	1.503-22	3133.	1.450-22	3184.	1.308-22	3235.	1.333-22	3287.	1.283-22	3338.	1.257-22
3389.	1.197-22	3445.	1.056-22	3504.	1.018-22	3563.	1.046-22	3622.	9.633-23	3681.	8.561-23	3740.	8.238-23

Note: Energy is secondary electron energy in eV.

Reference: These data were taken from L.H. Toburen, Phys. Rev. A 9, 2505 (1974).



Graphical Data I-2.A-24. Single differential cross section (secondary electron spectrum) for H^+ + Xe collisions. These data were taken from L. H. Toburen, Phys. Rev. A 9, 2505 (1974).

Section I-2.B. SECONDARY ELECTRON ENERGY SPECTRA FOR PROTON IMPACT IONIZATION OF THE MOLECULES H_2, O_2, N_2, H_2O, NH_3, and CH_4

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Tabular Data I-2.B-1. Single differential cross section (secondary electron spectra) for $H^+ + H_2$ collisions (units of m^2/eV).

Electron Energy (EV)	Proton Energy (keV) 5	7	10	15	20	30	50	70	100
1.5	9.24-22	1.09-21	9.35-22	1.06-21	1.17-21	1.49-21	1.97-21	1.69-21	1.38-21
~~2.0~~	~~1.01-21~~	~~1.05-21~~	~~1.05-21~~	~~1.14-21~~	~~1.26-21~~	~~1.61-21~~	~~2.01-21~~	~~1.81-21~~	~~1.54-21~~
3.0	6.52-22	9.26-22	1.03-21	1.18-21	1.29-21	1.61-21	1.85-21	1.75-21	1.52-21
~~5.0~~	~~3.80-22~~	~~5.90-22~~	~~7.33-22~~	~~1.01-21~~	~~1.18-21~~	~~1.44-21~~	~~1.56-21~~	~~1.45-21~~	~~1.24-21~~
7.5	2.16-22	3.63-22	4.87-22	6.99-22	9.15-22	1.21-21	1.26-21	1.14-21	9.43-22
~~10.0~~	~~1.28-22~~	~~2.12-22~~	~~3.13-22~~	~~4.95-22~~	~~6.62-22~~	~~9.98-22~~	~~1.04-21~~	~~9.33-22~~	~~7.52-22~~
15.0	4.61-23	8.71-23	1.35-22	2.52-22	3.80-22	6.15-22	7.43-22	6.68-22	5.16-22
~~20.0~~	~~1.86-23~~	~~3.73-23~~	~~6.41-23~~	~~1.38-22~~	~~2.27-22~~	~~3.74-22~~	~~5.44-22~~	~~5.00-22~~	~~3.78-22~~
30.0	4.96-24	8.22-24	1.89-23	4.77-23	9.23-23	1.79-22	2.86-22	3.10-22	2.35-22
~~50.0~~	~~2.90-25~~	~~1.45-24~~	~~1.58-24~~	~~5.38-24~~	~~1.31-23~~	~~4.40-23~~	~~8.97-23~~	~~1.10-22~~	~~1.07-22~~
75.0	* * *	2.87-25	8.82-26	4.23-25	7.83-25	6.20-24	2.80-23	4.16-23	4.31-23
~~100.0~~	~~8.00-26~~	~~1.90-25~~	~~2.82-26~~	~~1.17-25~~	~~8.09-26~~	~~8.51-25~~	~~8.11-24~~	~~1.84-23~~	~~2.18-23~~
130.0	* * *	2.17-25	* * *	4.71-26	5.55-27	8.42-26	1.42-24	6.48-24	1.11-23
~~160.0~~	~~4.62-26~~	~~1.96-25~~	~~2.05-27~~	~~3.66-26~~	~~2.56-27~~	~~1.60-26~~	~~1.89-25~~	~~1.90-24~~	~~5.85-24~~
200.0	* * *	2.24-25	* * *	5.11-26	1.51-27	2.31-27	2.46-26	2.51-25	1.94-24
~~250.0~~	~~2.00-25~~	~~8.47-26~~	~~2.56-27~~	~~7.61-26~~	~~1.20-27~~		~~7.02-27~~	~~1.62-26~~	~~3.41-25~~
300.0			1.06-27	1.40-26	6.64-28			4.41-27	5.17-26

Reference: These data were taken from M. E. Rudd, to be published (1979).

Tabular Data I-2.B-2. Single differential cross section (secondary electron spectra) for $H^+ + H_2$ collisions (units of m^2/eV).

Proton Energy =

ELECTRON ENERGY (EV)	100 keV	150 keV	200 keV	300 keV
2	1.346E-21	1.068E-21	9.335E-22	7.049E-22
4	1.162E-21	8.981E-22	8.134E-22	6.223E-22
6	9.886E-22	8.206E-22	6.669E-22	5.111E-22
8	8.220E-22	6.143E-22	5.523E-22	4.191E-22
10	6.880E-22	5.188E-22	4.584E-22	3.480E-22
15	5.048E-22	3.598E-22	3.050E-22	2.299E-22
20	3.837E-22	2.683E-22	2.232E-22	1.590E-22
25	3.048E-22	2.078E-22	1.691E-22	1.185E-22
30	2.456E-22	1.672E-22	1.314E-22	9.161E-23
35	2.042E-22	1.308E-22	1.068E-22	7.360E-23
40	1.681E-22	1.066E-22	8.466E-23	5.984E-23
50	1.174E-22	7.596E-23	6.021E-23	4.019E-23
60	8.077E-23	5.670E-23	4.356E-23	2.934E-23
70	5.601E-23	4.433E-23	3.334E-23	2.169E-23
80	4.087E-23	3.423E-23	2.600E-23	1.690E-23
90	2.980E-23	2.623E-23	2.084E-23	1.312E-23
100	2.243E-23	2.098E-23	1.713E-23	1.160E-23
125	1.223E-23	1.372E-23	1.041E-23	7.045E-24
150	7.067E-24	8.851E-24	7.062E-24	4.737E-24
175	4.000E-24	5.765E-24	4.451E-24	3.464E-24
200	1.960E-24	3.896E-24	3.153E-24	2.453E-24
250	3.729E-25	2.044E-24	1.694E-24	1.775E-24
300	1.255E-25	6.335E-25	1.076E-24	9.603E-25
350	2.044E-26	2.168E-25	6.450E-25	5.597E-25
400	4.938E-27	5.853E-26	3.322E-25	4.185E-25
450	8.569E-28		1.299E-25	3.259E-25
500			4.545E-26	2.506E-25
550			1.636E-26	1.782E-25
600			6.752E-27	1.118E-25
650			2.463E-27	5.783E-26
700			1.465E-27	2.578E-26
750			5.928E-29	9.301E-27
800			5.712E-29	1.951E-27
850			4.107E-28	8.515E-28
900				1.600E-27
950				4.248E-29

Reference: These data were taken from M. E. Rudd, C. A. Sautter, and C. L. Bailey, Phys. Rev. 151, 20 (1966).

Tabular Data I-2.B-3. Single differential cross section (secondary electron spectra) for $H^+ + H_2$ collisions (units of cm^2/eV).

Proton Energy = 300 keV

ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)
2.	1.107-17	4.	6.854-18	6.	5.206-18	8.	3.916-18	9.	3.009-18	11.	2.511-18
13.	2.117-18	15.	1.788-18	17.	1.487-18	19.	1.337-18	20.	1.168-18	22.	1.039-18
24.	9.148-19	26.	8.286-19	28.	7.603-19	30.	6.702-19	31.	6.080-19	33.	5.419-19
35.	4.907-19	37.	4.751-19	39.	4.391-19	41.	4.235-19	42.	3.902-19	44.	3.444-19
46.	3.349-19	48.	4.603-19	50.	2.889-19	52.	2.716-19	53.	2.505-19	55.	2.402-19
57.	2.385-19	59.	2.247-19	61.	2.121-19	63.	1.965-19	64.	1.858-19	66.	1.791-19
68.	1.701-19	70.	1.617-19	72.	1.590-19	74.	1.470-19	75.	1.454-19	77.	1.418-19
79.	1.336-19	81.	1.271-19	83.	1.189-19	85.	1.158-19	86.	1.080-19	88.	1.056-19
90.	1.011-19	92.	1.003-19	94.	9.468-20	96.	9.268-20	97.	8.892-20	99.	8.704-20
101.	8.232-20	103.	7.879-20	105.	7.658-20	107.	7.659-20	108.	7.529-20	110.	6.966-20
112.	7.027-20	114.	6.696-20	116.	6.295-20	118.	6.407-20	120.	5.951-20	121.	5.949-20
123.	6.053-20	125.	5.761-20	127.	5.621-20	129.	5.413-20	131.	5.348-20	132.	4.889-20
134.	4.958-20	136.	4.563-20	138.	4.695-20	140.	4.841-20	142.	4.511-20	143.	4.328-20
145.	4.264-20	147.	4.245-20	149.	3.922-20	151.	3.813-20	153.	3.928-20	154.	3.971-20
156.	3.879-20	158.	3.669-20	160.	3.707-20	162.	3.677-20	164.	3.560-20	165.	3.459-20
167.	3.265-20	169.	3.271-20	171.	3.176-20	173.	3.105-20	175.	3.004-20	176.	2.917-20
178.	2.851-20	180.	2.804-20	182.	2.787-20	184.	2.803-20	186.	2.625-20	187.	2.629-20
189.	2.513-20	191.	2.460-20	193.	2.521-20	195.	2.300-20	197.	2.449-20	198.	2.301-20
200.	2.289-20	202.	2.439-20	204.	2.383-20	206.	2.203-20	208.	2.116-20	209.	2.094-20
211.	2.010-20	213.	1.877-20	215.	1.997-20	217.	1.951-20	219.	1.887-20	220.	1.869-20
222.	1.839-20	224.	1.899-20	226.	1.742-20	228.	1.787-20	230.	1.726-20	231.	1.769-20
233.	1.676-20	235.	1.715-20	237.	1.652-20	239.	1.632-20	241.	1.705-20	243.	1.559-20
244.	1.547-20	246.	1.478-20	248.	1.546-20	250.	1.489-20	252.	1.424-20	254.	1.420-20
255.	1.441-20	257.	1.415-20	259.	1.463-20	261.	1.423-20	263.	1.347-20	265.	1.373-20
266.	1.297-20	268.	1.380-20	270.	1.313-20	272.	1.239-20	274.	1.311-20	276.	1.252-20
277.	1.203-20	279.	1.205-20	281.	1.194-20	283.	1.180-20	285.	1.193-20	287.	1.149-20
288.	1.161-20	290.	1.111-20	292.	1.091-20	294.	1.066-20	296.	1.110-20	298.	1.110-20
299.	1.051-20	301.	1.018-20	303.	9.788-21	305.	9.985-21	307.	1.016-20	309.	1.001-20
310.	9.063-21	312.	9.643-21	314.	9.663-21	316.	9.905-21	318.	9.809-21	320.	9.704-21
321.	9.175-21	323.	9.111-21	325.	8.883-21	327.	8.963-21	329.	8.837-21	331.	8.319-21
332.	8.982-21	334.	8.248-21	336.	8.472-21	338.	8.349-21	340.	7.863-21	342.	8.105-21
343.	8.177-21	345.	8.034-21	347.	7.909-21	349.	7.337-21	351.	7.997-21	353.	7.325-21
355.	7.626-21	356.	7.377-21	358.	7.364-21	360.	7.273-21	362.	7.364-21	364.	7.046-21
366.	7.317-21	367.	7.003-21	369.	6.734-21	371.	7.060-21	373.	6.867-21	375.	6.552-21
377.	6.847-21	380.	6.567-21	386.	6.369-21	391.	6.083-21	397.	5.941-21	402.	6.027-21
408.	5.565-21	413.	5.575-21	419.	5.289-21	424.	5.235-21	430.	5.115-21	435.	4.910-21
441.	4.725-21	446.	4.618-21	454.	4.516-21	463.	4.164-21	472.	4.182-21	481.	3.890-21
490.	3.571-21	500.	3.324-21	509.	3.102-21	518.	2.962-21	527.	2.806-21	536.	2.504-21
545.	2.260-21	555.	2.210-21	564.	1.926-21	573.	1.765-21	582.	1.576-21	591.	1.427-21
601.	1.255-21	610.	1.084-21	619.	9.110-22	628.	7.768-22	637.	7.192-22	646.	6.083-22
656.	4.739-22	665.	4.424-22	674.	3.497-22	685.	2.938-22	698.	2.053-22	711.	1.676-22
724.	1.267-22	736.	1.046-22	749.	7.310-23	762.	5.675-23	775.	4.111-23	788.	2.765-23
801.	2.281-23	814.	1.520-23	826.	1.150-23	839.	1.438-23	852.	4.996-24	865.	5.718-24
878.	2.725-24	891.	1.345-24	905.	7.365-25	922.	1.000-30				

Note: Energy is secondary electron energy in eV.

Reference: These data were taken from L.H. Toburen and W. E. Wilson, Phys. Rev. A 5, 247 (1972).

Tabular Data I-2.B-4. Single differential cross section (secondary electron spectra) for $H^+ + H_2$ collisions (units of cm^2/eV).

Proton Energy = 500 keV

ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)
2.	5.410-18	4.	3.980-18	6.	3.209-18	8.	2.562-18	9.	2.036-18	11.	1.670-18
13.	1.403-18	15.	1.231-18	17.	1.005-18	19.	8.671-19	20.	7.960-19	22.	7.158-19
24.	6.133-19	26.	5.453-19	28.	4.771-19	30.	4.294-19	31.	3.883-19	33.	3.389-19
35.	3.249-19	37.	3.024-19	39.	2.717-19	41.	2.473-19	42.	2.346-19	44.	2.080-19
46.	1.945-19	48.	1.888-19	50.	1.759-19	52.	1.631-19	53.	1.520-19	55.	1.475-19
57.	1.383-19	59.	1.302-19	61.	1.235-19	63.	1.192-19	64.	1.141-19	66.	1.093-19
68.	1.011-19	70.	4.574-20	72.	9.507-20	74.	8.966-20	75.	8.433-20	77.	8.125-20
79.	8.004-20	81.	7.742-20	83.	7.185-20	85.	6.661-20	86.	6.572-20	88.	6.337-20
90.	6.321-20	92.	6.077-20	94.	5.730-20	96.	5.610-20	97.	5.515-20	99.	5.285-20
101.	5.051-20	103.	4.808-20	105.	4.740-20	107.	4.695-20	108.	4.478-20	110.	4.361-20
112.	4.328-20	114.	3.993-20	116.	3.910-20	118.	3.906-20	120.	3.985-20	121.	3.730-20
123.	3.566-20	125.	3.515-20	127.	3.337-20	129.	3.324-20	131.	3.186-20	132.	3.131-20
134.	3.082-20	136.	3.035-20	138.	2.904-20	140.	2.991-20	142.	2.852-20	143.	2.824-20
145.	2.610-20	147.	2.040-20	149.	2.513-20	151.	2.529-20	153.	2.472-20	154.	2.545-20
156.	2.386-20	158.	2.337-20	160.	2.339-21	162.	2.274-20	164.	2.235-20	165.	2.146-20
167.	2.081-20	169.	2.055-20	171.	1.925-20	173.	1.964-20	175.	1.970-20	176.	1.877-20
178.	1.880-20	180.	1.838-20	182.	1.842-20	184.	1.802-20	186.	1.716-20	187.	1.659-20
189.	1.651-20	191.	1.611-20	193.	1.515-20	195.	1.569-20	197.	1.536-20	198.	1.491-20
200.	1.509-20	202.	1.567-20	204.	1.485-20	206.	1.450-20	208.	1.330-20	209.	1.382-20
211.	1.395-20	213.	1.377-20	215.	1.312-20	217.	1.287-20	219.	1.244-20	220.	1.223-20
222.	1.157-20	224.	1.211-20	226.	1.155-20	228.	1.225-20	230.	1.170-20	231.	1.153-20
233.	1.125-20	235.	1.074-20	237.	1.049-20	239.	1.073-20	241.	1.063-20	243.	1.039-20
244.	1.004-20	246.	1.064-20	248.	9.615-21	250.	9.606-21	252.	9.355-21	254.	9.340-21
255.	8.487-21	257.	4.181-21	259.	9.232-21	261.	8.792-21	263.	8.679-21	265.	8.846-21
266.	8.142-21	268.	8.354-21	270.	8.528-21	272.	8.116-21	274.	7.777-21	276.	7.712-21
277.	7.044-21	279.	7.410-21	281.	7.655-21	283.	7.613-21	285.	7.744-21	287.	7.181-21
288.	7.155-21	290.	7.520-21	292.	6.692-21	294.	6.740-21	296.	6.949-21	298.	6.825-21
299.	6.786-21	301.	6.092-21	303.	6.278-21	305.	6.510-21	307.	6.462-21	309.	6.082-21
310.	5.977-21	312.	5.893-21	314.	5.921-21	316.	5.952-21	318.	5.761-21	320.	5.859-21
321.	5.685-21	323.	5.784-21	325.	5.680-21	327.	5.690-21	329.	5.169-21	331.	5.169-21
332.	5.134-21	334.	5.268-21	336.	5.083-21	338.	4.852-21	340.	4.949-21	342.	5.085-21
343.	5.271-21	345.	4.774-21	347.	4.897-21	349.	4.800-21	351.	4.737-21	353.	4.809-21
355.	4.729-21	356.	4.406-21	358.	4.474-21	360.	4.529-21	362.	4.576-21	364.	4.682-21
366.	4.521-21	367.	4.223-21	369.	4.200-21	371.	4.135-21	373.	4.088-21	375.	4.245-21
377.	4.302-21	380.	3.989-21	386.	3.919-21	391.	3.814-21	397.	3.664-21	402.	3.516-21
408.	3.555-21	413.	3.366-21	419.	3.203-21	424.	3.194-21	430.	3.103-21	435.	3.096-21
441.	2.960-21	446.	2.950-21	454.	2.774-21	463.	2.720-21	472.	2.633-21	481.	2.506-21
490.	2.424-21	500.	2.372-21	509.	2.211-21	518.	2.197-21				
527.	2.148-21	536.	2.043-21	545.	1.987-21	555.	1.972-21	564.	1.921-21	573.	1.819-21
582.	1.842-21	591.	1.750-21	601.	1.675-21	610.	1.651-21	619.	1.638-21	628.	1.545-21
637.	1.558-21	646.	1.527-21	656.	1.480-21	665.	1.423-21	674.	1.374-21	685.	1.343-21
698.	1.320-21	711.	1.237-21	724.	1.232-21	736.	1.153-21	749.	1.124-21	762.	1.064-21
775.	1.021-21	788.	9.962-22	801.	9.546-22	814.	9.038-22	826.	8.613-22	839.	8.234-22
852.	7.781-22	865.	7.413-22	878.	7.190-22	891.	6.673-22	905.	6.225-22	922.	5.748-22
938.	4.992-22	955.	4.481-22	971.	3.969-22	988.	3.479-22	1004.	2.879-22	1021.	2.472-22
1038.	2.065-22	1054.	1.673-22	1071.	1.316-22	1087.	1.060-22	1104.	9.336-23	1120.	7.334-23
1138.	4.976-23	1159.	3.320-23	1179.	2.397-23	1199.	1.892-23	1219.	1.292-23	1239.	1.029-23
1260.	7.172-24	1280.	4.873-24	1300.	3.903-24	1320.	1.837-24	1340.	1.151-24	1362.	8.502-25
1386.	7.655-25	1410.	1.000-30	1434.	1.000-30	1458.	1.000-30				

Note: Energy is secondary electron energy in eV.

Reference: These data were taken from L. H. Toburen, and E. W. Wilson, Phys. Rev. A 5, 247 (1972).

Tabular Data I-2.B-5. Single differential cross section (secondary electron spectra) for $H^+ + H_2$ collisions (units of cm^2/eV).

Proton Energy = 750 keV

ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)
3.	3.375-18	7.	2.244-18	10.	1.404-18	14.	9.420-19	18.	6.667-19	21.	5.107-19
25.	3.990-19	29.	3.173-19	33.	2.600-19	36.	2.095-19	40.	1.820-19	44.	1.541-19
47.	1.345-19	51.	1.203-19	55.	1.054-19	58.	9.093-20	62.	8.212-20	66.	7.328-20
69.	6.686-20	73.	5.854-20	77.	5.586-20	80.	5.009-20	84.	4.725-20	88.	4.317-20
92.	3.842-20	95.	3.619-20	99.	3.575-20	103.	3.153-20	106.	3.026-20	110.	2.869-20
114.	2.622-20	117.	2.326-20	121.	2.376-20	125.	2.185-20	128.	2.066-20	132.	1.925-20
136.	1.914-20	140.	1.771-20	143.	1.663-20	147.	1.554-20	151.	1.500-20	154.	1.450-20
158.	1.424-20	162.	1.330-20	165.	1.317-20	169.	1.253-20	173.	1.117-20	176.	1.162-20
180.	1.070-20	184.	1.070-20	187.	9.842-21	191.	9.571-21	195.	9.442-21	199.	9.806-21
202.	9.050-21	206.	8.555-21	210.	8.231-21	213.	7.979-21	217.	7.627-21	221.	7.321-21
219.	7.311-21	223.	7.027-21	226.	6.631-21	230.	6.111-21	233.	6.879-21	237.	6.080-21
241.	5.845-21	244.	5.672-21	248.	5.579-21	251.	5.424-21	255.	5.140-21	259.	4.810-21
262.	5.252-21	266.	4.915-21	276.	5.141-21	280.	4.658-21	283.	4.703-21	287.	4.663-21
291.	4.138-21	295.	4.205-21	298.	4.032-21	302.	4.223-21	306.	3.976-21	309.	3.738-21
313.	3.604-21	317.	3.676-21	320.	3.557-21	324.	3.491-21	328.	3.364-21	331.	3.343-21
335.	3.122-21	339.	3.074-21	342.	3.260-21	346.	2.711-21	350.	3.027-21	354.	3.087-21
357.	2.867-21	361.	2.646-21	365.	2.785-21	368.	2.763-21	372.	2.749-21	376.	2.609-21
379.	2.568-21	383.	2.367-21	387.	2.405-21	390.	2.376-21	394.	2.073-21	398.	2.193-21
402.	2.286-21	405.	2.227-21	409.	2.189-21	413.	2.289-21	416.	2.255-21	420.	2.037-21
424.	2.027-21	427.	1.971-21	431.	2.056-21	435.	1.991-21	439.	1.922-21	442.	1.837-21
446.	1.687-21	449.	1.843-21	453.	1.701-21	457.	1.637-21	461.	1.737-21	464.	1.716-21
468.	1.516-21	472.	1.643-21	475.	1.567-21	479.	1.527-21	483.	1.492-21	486.	1.522-21
490.	1.494-21	494.	1.473-21	497.	1.376-21	501.	1.465-21	505.	1.327-21	509.	1.461-21
512.	1.225-21	516.	1.273-21	520.	1.361-21	523.	1.391-21	527.	1.248-21	531.	1.219-21
534.	1.244-21	538.	1.270-21	542.	1.200-21	545.	1.255-21	549.	1.203-21	553.	1.072-21
556.	1.249-21	560.	1.137-21	564.	1.144-21	568.	1.187-21	571.	1.089-21	575.	1.084-21
579.	9.849-22	582.	9.829-22	586.	1.002-21	590.	1.080-21	593.	1.010-21	597.	1.011-21
601.	1.005-21	604.	1.060-21	608.	9.496-22	612.	9.958-22	616.	9.645-22	619.	1.016-21
623.	9.361-22	627.	9.613-22	630.	9.206-22	634.	9.521-22	638.	9.245-22	641.	8.662-22
645.	9.720-22	649.	8.251-22	652.	8.975-22	656.	8.160-22	660.	8.478-22	664.	8.819-22
667.	8.234-22	671.	7.622-22	675.	8.011-22	679.	8.340-22	682.	8.024-22	686.	8.811-22
689.	8.017-22	693.	8.012-22	697.	6.922-22	700.	8.013-22	704.	7.212-22	708.	7.439-22
711.	7.869-22	715.	7.030-22	719.	7.129-22	723.	7.374-22	726.	7.078-22	730.	7.055-22
734.	6.869-22	737.	6.452-22	741.	6.325-22	745.	6.804-22	749.	5.834-22	752.	6.015-22
756.	6.615-22	763.	6.062-22	774.	5.962-22	785.	5.933-22	796.	5.840-22	807.	5.541-22
818.	5.146-22	830.	5.255-22	841.	5.422-22	852.	4.991-22	863.	5.121-22	874.	5.145-22
885.	4.943-22	896.	4.980-22	911.	4.817-22	929.	4.545-22	948.	4.485-22	966.	4.362-22
985.	4.141-22	1003.	4.067-22	1021.	4.089-22	1040.	3.612-22	1059.	3.605-22	1077.	3.460-22
1095.	3.537-22	1114.	3.457-22	1132.	3.301-22	1151.	3.23[illegible]-22	1169.	3.336-22	1187.	3.186-22
1206.	3.136-22	1224.	2.979-22	1243.	3.004-22	1261.	2.94[illegible]-22	1280.	2.890-22	1298.	2.654-22
1317.	2.580-22	1335.	2.432-22	1354.	2.383-22	1376.	2.223-22	1402.	1.979-22	1427.	1.740-22
1453.	1.464-22	1479.	1.324-22	1505.	1.017-22	1531.	8.144-23	1556.	6.283-23	1582.	4.836-23
1608.	3.581-23	1634.	3.018-23	1660.	2.002-23	1686.	1.475-23	1711.	1.158-23	1737.	9.985-24
1763.	6.306-24	1789.	4.031-24	1815.	3.497-24	1844.	1.218-24				

Note: Energy is secondary electron energy in eV.

Reference: These data were taken from L.H. Toburen and W.E. Wilson, Phys. Rev. A 5, 247 (1972).

Tabular Data I-2.B-6. Single differential cross section (secondary electron spectra) for $H^+ + H_2$ collisions (units of cm^2/eV).

Proton Energy = 1 MeV

ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)
2.	1.374-18	4.	1.724-18	6.	1.625-18	8.	1.351-18	9.	1.095-18	11.	9.136-19
13.	7.375-19	15.	6.075-19	17.	5.174-19	19.	4.446-19	20.	3.828-19	22.	3.404-19
24.	2.990-19	26.	2.548-19	28.	2.371-19	30.	1.993-19	31.	1.881-19	33.	1.698-19
35.	1.524-19	37.	1.404-19	39.	1.370-19	41.	1.203-19	42.	1.175-19	44.	1.093-19
46.	9.545-20	48.	9.126-20	50.	8.923-20	52.	8.144-20	53.	7.829-20	55.	6.904-20
57.	6.679-20	59.	6.241-20	61.	6.042-20	63.	5.651-20				
ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)
64.	5.553-20	66.	5.064-20	68.	4.873-20	70.	4.668-20	72.	4.283-20	74.	4.201-20
75.	3.927-20	77.	3.846-20	79.	3.610-20	81.	3.484-20	83.	3.425-20	85.	3.149-20
86.	3.168-20	88.	2.830-20	90.	2.882-20	92.	2.728-20	94.	2.668-20	96.	2.628-20
97.	2.435-20	99.	2.371-20	101.	2.264-20	103.	2.135-20	105.	2.168-20	107.	2.123-20
108.	2.042-20	110.	2.014-20	112.	1.869-20	114.	1.815-20	116.	1.836-20	118.	1.762-20
120.	1.711-20	121.	1.604-20	123.	1.573-20	125.	1.500-20	127.	1.549-20	129.	1.462-20
131.	1.436-20	132.	1.336-20	134.	1.342-20	136.	1.247-20	138.	1.252-20	140.	1.200-20
142.	1.242-20	143.	1.158-20	145.	1.153-20	147.	1.076-20	149.	1.050-20	151.	1.069-20
153.	9.206-21	154.	1.047-20	156.	9.732-21	158.	9.875-21	160.	9.682-21	162.	9.302-21
164.	9.345-21	165.	9.143-21	167.	8.865-21	169.	8.682-21	171.	8.394-21	173.	8.207-21
175.	8.346-21	176.	7.768-21	178.	7.231-21	180.	7.493-21	182.	7.282-21	184.	7.471-21
186.	7.326-21	187.	7.229-21	189.	6.592-21	191.	6.181-21	193.	6.961-21	195.	6.514-21
197.	6.406-21	198.	6.335-21	200.	6.213-21	202.	6.216-21	204.	5.990-21	206.	6.174-21
208.	5.539-21	209.	5.613-21	211.	5.776-21	213.	5.107-21	215.	5.461-21	217.	5.190-21
219.	5.030-21	220.	4.795-21	222.	4.767-21	224.	5.162-21	226.	4.915-21	228.	4.677-21
230.	5.176-21	231.	4.910-21	233.	4.799-21	235.	4.725-21	237.	4.610-21	239.	4.427-21
241.	4.452-21	243.	4.637-21	244.	4.331-21	246.	4.208-21	248.	3.979-21	250.	4.353-21
252.	4.268-21	254.	4.006-21	255.	3.830-21	257.	3.512-21	259.	3.791-21	261.	3.694-21
263.	3.607-21	265.	3.591-21	266.	3.461-21	268.	3.319-21	270.	3.401-21	272.	3.242-21
274.	3.338-21	276.	3.236-21	277.	3.461-21	279.	3.268-21	281.	3.248-21	283.	3.321-21
285.	2.959-21	287.	3.234-21	288.	3.095-21	290.	3.050-21	292.	2.986-21	294.	3.114-21
296.	2.973-21	298.	2.824-21	299.	2.820-21	301.	2.908-21	303.	2.983-21	305.	2.857-21
307.	2.641-21	309.	2.595-21	310.	2.571-21	312.	2.574-21	314.	2.496-21	316.	2.610-21
318.	2.678-21	320.	2.412-21	321.	2.347-21	323.	2.500-21	325.	2.393-21	327.	2.423-21
329.	2.329-21	331.	2.406-21	332.	2.291-21	334.	2.197-21	336.	2.187-21	338.	2.395-21
340.	2.353-21	342.	2.341-21	343.	2.232-21	345.	2.316-21	347.	2.266-21	349.	2.203-21
351.	1.976-21	353.	2.112-21	355.	1.835-21	356.	2.093-21	358.	2.018-21	360.	1.899-21
362.	2.075-21	364.	2.034-21	366.	2.071-21	367.	1.726-21	369.	1.998-21	371.	1.903-21
373.	1.749-21	375.	1.938-21	377.	1.800-21	380.	1.779-21	385.	1.720-21	391.	1.760-21
397.	1.617-21	402.	1.581-21	408.	1.530-21	413.	1.539-21	419.	1.461-21	424.	1.424-21
430.	1.377-21	435.	1.343-21	441.	1.315-21	446.	1.318-21	454.	1.231-21	463.	1.212-21
472.	1.126-21	481.	1.143-21	490.	1.077-21	500.	1.040-21	509.	9.979-22	518.	1.005-21
527.	9.936-22	536.	9.573-22	545.	8.979-22	555.	8.544-22	564.	8.646-22	573.	8.479-22
582.	8.166-22	591.	7.553-22	601.	7.700-22	610.	7.051-22	619.	6.898-22	628.	6.347-22
637.	6.410-22	646.	6.410-22	656.	6.166-22	665.	5.831-22	674.	6.039-22	685.	5.514-22
698.	5.525-22	711.	5.236-22	724.	5.006-22	736.	4.858-22	749.	4.621-22	762.	4.796-22
775.	4.453-22	788.	4.374-22	801.	4.245-22	814.	4.054-22	826.	3.976-22	839.	3.799-22
852.	3.999-22	865.	3.818-22	878.	3.780-22	891.	3.457-22	905.	3.277-22	922.	3.262-22
938.	3.079-22	955.	3.034-22	971.	2.974-22	988.	2.786-22	1004.	2.608-22	1021.	2.539-22
1038.	2.500-22	1054.	2.316-22	1071.	2.283-22	1087.	2.259-22	1104.	2.166-22	1120.	2.234-22
1138.	2.065-22	1159.	2.120-22	1179.	2.144-22	1199.	1.992-22	1219.	1.937-22	1239.	1.905-22
1260.	1.901-22	1280.	1.455-22	1300.	1.769-22	1320.	1.643-22	1340.	1.622-22	1362.	1.574-22
1386.	1.570-22	1410.	1.568-22	1434.	1.493-22	1458.	1.448-22	1482.	1.409-22	1506.	1.385-22
1530.	1.317-22	1555.	1.323-22	1577.	1.289-22	1603.	1.249-22	1631.	1.252-22	1658.	1.210-22
1686.	1.123-22	1713.	1.071-22	1741.	1.016-22	1768.	9.939-23	1796.	9.810-23	1825.	9.396-23
1856.	8.757-23	1888.	8.127-23	1919.	7.201-23	1950.	6.529-23	1981.	5.330-23	2012.	4.462-23
2045.	3.415-23	2080.	2.795-23	2115.	1.914-23	2150.	1.402-23	2185.	1.045-23	2220.	7.517-24
2255.	5.128-24	2291.	3.203-24	2330.	2.014-24	2369.	1.243-24	2407.	6.240-25	2446.	1.624-25

Note: Energy is secondary electron energy in eV.

Reference: These data were taken from L.H. Toburen and W.E. Wilson, Phys. Rev. A 5, 247 (1972).

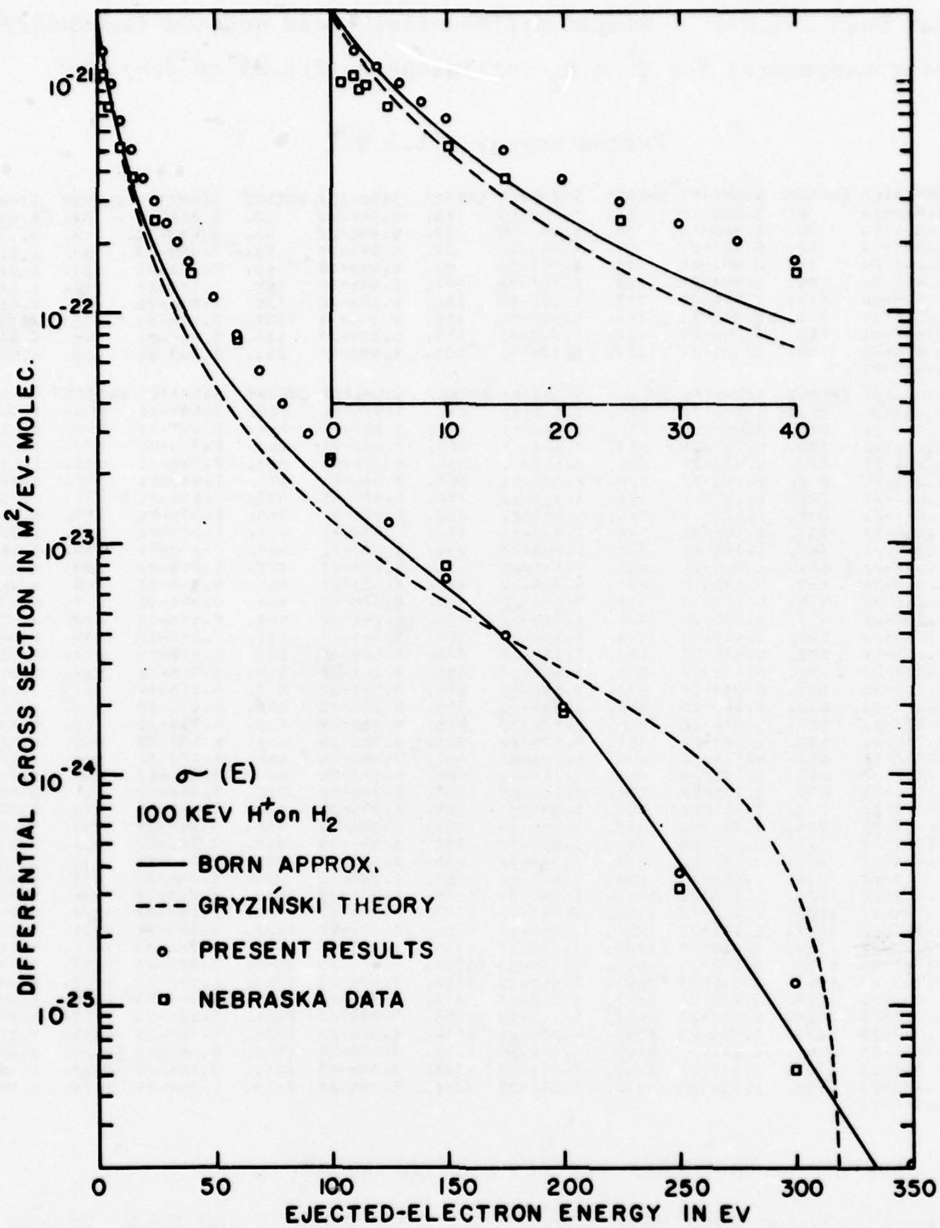
Tabular Data I-2.B-7. Single differential cross section (secondary electron spectra) for $H^+ + H_2$ collisions (units of cm^2/eV).

Proton Energy = 1.5 MeV

ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)
4.	1.918-18	8.	1.065-18	11.	6.720-19	15.	4.568-19	19.	3.210-19	22.	2.439-19
26.	1.856-19	30.	1.496-19	34.	1.187-19	37.	9.954-20	41.	8.643-20	45.	7.377-20
48.	6.322-20	52.	5.616-20	56.	4.886-20	59.	4.342-20	63.	3.846-20	67.	3.514-20
71.	3.158-20	74.	2.901-20	78.	2.647-20	82.	2.442-20	85.	2.321-20	89.	2.073-20
93.	1.841-20	96.	1.850-20	100.	1.707-20	104.	1.593-20	109.	1.489-20	111.	1.385-20
115.	1.314-20	119.	1.196-20	122.	1.152-20	126.	1.108-20	130.	1.040-20	133.	9.962-21
137.	9.361-21	141.	8.973-21	145.	8.426-21	148.	8.104-21	152.	7.426-21	156.	7.735-21
159.	7.282-21	163.	6.708-21	167.	6.592-21	170.	6.357-21	174.	5.948-21	178.	5.493-21
182.	5.576-21	185.	5.363-21	189.	5.120-21	193.	4.803-21	196.	4.707-21	200.	4.545-21
204.	4.635-21										
ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)
207.	4.281-21	211.	4.200-21	215.	3.937-21	219.	3.916-21	222.	3.657-21	226.	3.644-21
230.	3.704-21	233.	3.552-21	237.	3.219-21	241.	3.321-21	244.	3.297-21	248.	3.134-21
252.	3.055-21	256.	2.747-21	259.	2.408-21	263.	2.674-21	267.	2.710-21	270.	2.556-21
274.	2.462-21	278.	2.438-21	281.	2.414-21	285.	2.374-21	289.	2.264-21	293.	2.297-21
296.	2.295-21	300.	2.146-21	304.	2.060-21	307.	2.086-21	311.	1.945-21	315.	1.897-21
318.	1.883-21	322.	1.823-21	326.	1.811-21	330.	1.854-21	333.	1.645-21	337.	1.759-21
341.	1.677-21	344.	1.623-21	348.	1.622-21	352.	1.601-21	355.	1.576-21	359.	1.511-21
363.	1.452-21	367.	1.407-21	370.	1.442-21	374.	1.437-21	378.	1.329-21	381.	1.330-21
385.	1.339-21	389.	1.306-21	392.	1.249-21	396.	1.237-21	400.	1.279-21	403.	1.169-21
407.	1.146-21	411.	1.240-21	415.	1.140-21	418.	1.176-21	422.	1.048-21	426.	1.074-21
429.	1.048-21	433.	9.878-22	437.	9.769-22	440.	1.033-21	444.	9.720-22	448.	9.669-22
452.	9.768-22	455.	9.138-22	459.	9.250-22	463.	9.220-22	466.	9.001-22	470.	8.695-22
474.	8.292-22	477.	8.523-22	481.	8.709-22	485.	8.061-22	489.	8.457-22	492.	8.473-22
496.	8.273-22	500.	7.509-22	503.	7.568-22	507.	7.341-22	511.	7.169-22	514.	6.991-22
518.	7.157-22	522.	6.871-22	526.	7.167-22	529.	6.615-22	533.	6.812-22	537.	6.724-22
540.	6.894-22	544.	6.130-22	548.	6.601-22	551.	6.205-22	555.	5.904-22	559.	5.940-22
563.	5.916-22	568.	6.053-22	570.	5.686-22	574.	5.882-22	577.	5.816-22	581.	5.193-22
585.	5.340-22	588.	5.344-22	592.	5.034-22	596.	5.336-22	600.	5.213-22	603.	5.567-22
607.	5.224-22	611.	5.034-22	614.	4.974-22	618.	4.855-22	622.	4.918-22	625.	4.899-22
629.	4.764-22	633.	4.507-22	637.	4.439-22	640.	4.520-22	644.	4.497-22	648.	4.526-22
651.	4.452-22	655.	4.739-22	659.	4.266-22	662.	3.940-22	666.	4.180-22	670.	4.275-22
674.	4.055-22	677.	3.799-22	681.	4.156-22	685.	4.243-22	689.	3.871-22	692.	3.933-22
696.	3.922-22	699.	3.935-22	703.	3.656-22	707.	3.885-22	711.	3.744-22	714.	3.474-22
718.	3.842-22	722.	3.433-22	725.	3.533-22	729.	3.375-22	733.	3.481-22	736.	3.645-22
740.	3.354-22	744.	3.342-22	747.	3.448-22	751.	3.220-22	755.	3.119-22	759.	3.090-22
766.	3.162-22	777.	3.110-22	788.	2.853-22	799.	2.893-22	810.	2.731-22	821.	2.532-22
833.	2.494-22	844.	2.493-22	855.	2.383-22	866.	2.158-22	877.	2.017-22	888.	1.952-22
899.	1.667-22	914.	1.658-22	932.	1.451-22	951.	1.326-22	969.	1.289-22	988.	1.216-22
1006.	1.242-22	1025.	1.243-22	1043.	1.154-22	1062.	1.231-22	1080.	1.201-22	1099.	1.205-22
1117.	1.224-22	1136.	1.220-22	1154.	1.247-22	1173.	1.245-22	1191.	1.159-22	1210.	1.210-22
1228.	1.167-22	1247.	1.171-22	1265.	1.189-22	1284.	1.174-22	1302.	1.178-22	1321.	1.098-22
1339.	1.125-22	1358.	1.080-22	1380.	1.000-22	1406.	1.017-22	1432.	9.780-23	1458.	9.186-23
1484.	9.161-23	1509.	8.806-23	1535.	8.206-23	1561.	7.876-23	1587.	7.522-23	1613.	7.787-23
1639.	7.369-23	1665.	7.616-23	1691.	7.468-23	1717.	7.004-23	1743.	6.742-23	1768.	6.784-23
1794.	6.674-23	1824.	6.736-23	1857.	6.712-23	1890.	6.540-23	1924.	6.342-23	1957.	6.091-23
1990.	5.815-23	2024.	5.602-23	2057.	5.463-23	2090.	5.224-23	2124.	5.130-23	2157.	5.226-23
2190.	4.943-23	2223.	5.028-23	2257.	4.874-23	2294.	4.804-23	2334.	4.760-23	2375.	4.597-23
2416.	4.426-23	2456.	4.277-23	2497.	4.095-23	2538.	3.802-23	2579.	3.684-23	2619.	3.603-23
2660.	3.633-23	2701.	3.545-23	2745.	3.551-23	2793.	3.354-23	2841.	3.124-23	2889.	2.644-23
2937.	2.190-23	2985.	1.832-23	3033.	1.336-23	3082.	1.005-23	3130.	6.897-24	3178.	4.452-24
3230.	1.000-30										

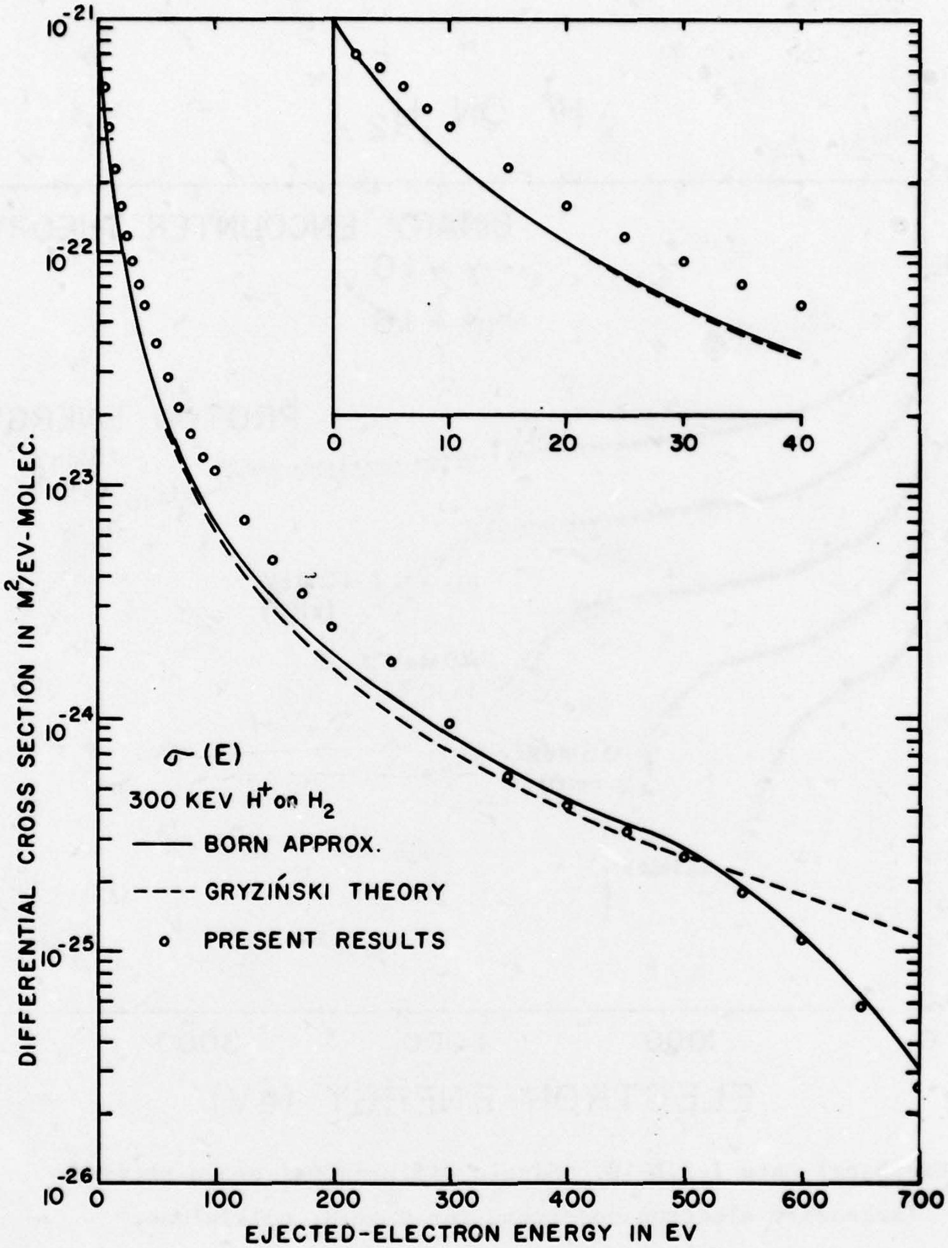
Note: Energy is secondary electron energy in eV.

Reference: These data were taken from L.H. Toburen and E. W. Wilson, Phys. Rev. A 5, 247 (1972).



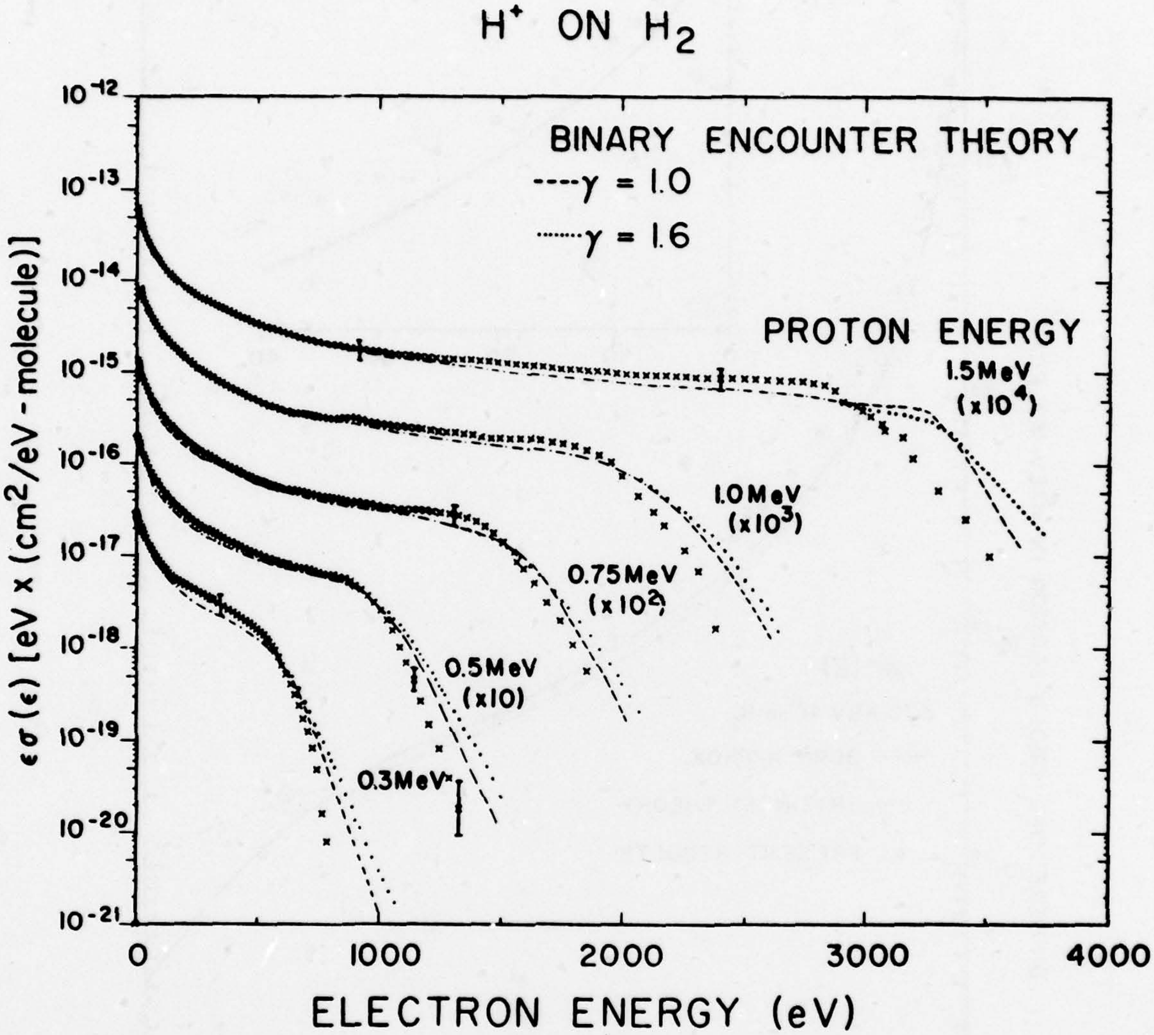
Graphical Data I-2.B-8. Single differential cross section (secondary electron spectrum) for $H^+ + H_2$ collisions.

These data were taken from M. E. Rudd, C. A. Sautter, and C. L. Bailey, Phys. Rev. 151, 20 (1966); present results are from reference and "Nebraska Data" are from M. E. Rudd and T. Jorgensen, Phys. Rev. 130, 1444 (1963).



Graphical Data I-2.B-9. Single differential cross section (secondary electron spectrum) for $H^+ + H_2$ collisions.

These data were taken from M. E. Rudd, C. A. Sautter, and C. L. Bailey, Phys. Rev. 151, 20 (1966); present results are from that reference and "Nebraska Data" are from M. E. Rudd and T. Jorgensen, Phys. Rev. 130, 1444 (1963).



Graphical Data I-2.B-10. Single differential cross section (secondary electron spectrum) for $H^+ + H_2$ collisions.

These data were taken from L. H. Toburen and W. E. Wilson, Phys. Rev. A 5, 247 (1972).

Tabular Data I-2.B-11. Single differential cross section (secondary electron spectra) for $H^+ + N_2$ collisions (units of m^2/eV).

Electron Energy (eV)	Proton Energy (keV) 10	15	20	30	50	70
1.5	3.86-21	3.47-21	2.97-21	2.87-21	2.69-21	2.58-21
2.0	3.62-21	3.34-21	3.27-21	2.96-21	2.78-21	2.63-21
3.0	2.93-21	2.98-21	2.92-21	2.81-21	2.59-21	2.45-21
5.0	2.20-21	2.41-21	2.46-21	2.41-21	2.19-21	2.02-21
7.5	1.50-21	1.84-21	2.00-21	2.01-21	1.83-21	1.68-21
10.0	1.09-21	1.38-21	1.62-21	1.71-21	1.57-21	1.43-21
15.0	5.51-22	7.75-22	9.62-22	1.22-21	1.20-21	1.09-21
20.0	2.64-22	4.66-22	6.07-22	7.79-22	9.35-22	8.48-22
30.0	1.03-22	1.90-22	2.80-22	4.18-22	5.78-22	5.81-22
50.0	1.36-23	3.32-23	5.90-23	1.27-22	2.14-22	2.60-22
75.0	1.95-24	4.83-24	1.10-23	3.09-23	7.72-23	1.06-22
100.0	3.52-25	1.06-24	2.11-24	7.70-24	2.89-23	4.90-23
130.0	1.16-25	2.95-25	4.84-25	1.58-24	8.75-24	1.94-23
160.0	3.19-26	9.08-26	1.15-25	3.64-25	2.62-24	7.53-24
200.0	6.13-27	4.96-26	1.86-26	6.56-26	4.71-25	1.99-24
250.0	1.08-26	5.80-26	2.70-26	3.04-27	9.67-26	4.21-25
300.0			5.44-27		3.70-26	1.28-25

Reference: These data were taken from M. E. Rudd, to be published (1979).

Tabular Data I-2.B-12. Single differential cross section (secondary electron spectra) for $H^+ + N_2$ collisions (units of cm^2/eV).

Electron Energy (eV)	Proton Energy (keV) 50	100	150	200	250	300
0.0	1.769E-17	1.260E-17	1.086E-17	1.026E-17	8.940E-18	8.433E-18
1.49	2.013E-17	1.581E-17	1.342E-17	1.225E-17	1.072E-17	9.892E-18
3.41	2.543E-17	2.151E-17	1.767E-17	1.542E-17	1.353E-17	1.212E-17
5.34	2.164E-17	1.829E-17	1.562E-17	1.357E-17	1.205E-17	1.071E-17
7.26	1.892E-17	1.597E-17	1.372E-17	1.212E-17	1.081E-17	9.770E-18
9.18	1.468E-17	1.416E-17	1.209E-17	1.071E-17	9.593E-18	8.690E-18
11.11	1.512E-17	1.279E-17	1.108E-17	9.864E-18	9.017E-19	8.176E-18
13.03	1.300E-17	1.139E-17	9.993E-18	8.842E-18	8.109E-18	7.335E-18
17.15	1.092E-17	8.762E-18	7.403E-18	6.467E-18	5.788E-18	5.197E-18
21.27	8.879E-18	6.868E-18	5.709E-18	4.931E-18	4.343E-18	3.876E-18
25.40	7.102E-18	5.751E-18	4.649E-18	3.947E-18	3.435E-18	3.043E-18
29.52	5.577E-18	5.005E-18	3.994E-18	3.392E-18	2.930E-18	2.602E-18
33.64	4.492E-18	4.427E-18	3.504E-18	2.958E-18	2.552E-18	2.243E-18
37.76	3.684E-18	3.938E-18	3.093E-18	2.580E-18	2.198E-18	1.933E-18
47.38	2.430E-18	3.009E-18	2.365E-18	1.914E-18	1.604E-18	1.402E-18
57.00	1.598E-18	2.224E-18	1.840E-18	1.481E-18	1.223E-18	1.057E-18
66.62	1.078E-18	1.640E-18	1.497E-18	1.192E-18	9.741E-19	8.354E-19
76.23	7.276E-19	1.251E-18	1.219E-18	9.926E-19	8.003E-19	6.796E-19
85.85	4.951E-19	9.706E-19	9.608E-19	8.346E-19	6.721E-19	5.632E-19
95.47	3.331E-19	7.608E-19	7.868E-19	7.024E-19	5.663E-19	4.739E-19
109.21	1.888E-19	5.423E-19	5.840E-19	5.494E-19	4.532E-19	3.752E-19
122.95	1.074E-19	3.933E-19	4.429E-19	4.221E-19	3.636E-19	3.028E-19
136.69	6.026E-20	2.855E-19	3.436E-19	3.326E-19	2.967E-19	2.520E-19
150.43	3.374E-20	2.055E-19	2.692E-19	2.657E-19	2.390E-19	2.078E-19
164.17	1.960E-20	1.468E-19	2.112E-19	2.129E-19	1.936E-19	1.732E-19
177.91	1.121E-20	1.046E-19	1.681E-19	1.747E-19	1.596E-19	1.430E-19
191.65	6.470E-21	7.442E-20	1.343E-19	1.449E-19	1.334E-19	1.205E-19
205.39	4.084E-21	5.259E-20	1.082E-19	1.204E-19	1.131E-19	1.021E-19
219.13	2.348E-21	3.677E-20	8.597E-20	1.012E-19	9.563E-20	8.744E-20
232.87	1.540E-21	2.584E-20	6.881E-20	8.579E-20	8.258E-20	7.578E-20
246.61	1.010E-21	1.757E-20	5.447E-20	7.261E-20	7.239E-20	6.650E-20
260.35	8.123E-22	1.225E-20	4.336E-20	6.157E-20	6.207E-20	5.808E-20
274.09	4.839E-22	8.541E-21	3.430E-20	5.264E-20	5.443E-20	5.141E-20
287.83	4.562E-22	5.908E-21	2.681E-20	4.519E-20	4.773E-20	4.589E-20
342.79	2.260E-22	2.726E-21	1.268E-20	[illegible]	3.696E-20	3.882E-20
397.75	4.853E-23	3.794E-22	3.174E-21	1.065E-20	1.718E-20	1.914E-20
452.71	1.906E-24	1.174E-22	9.621E-22	4.521E-21	9.630E-21	1.247E-20
507.67	2.746E-24	4.604E-23	3.337E-22	1.827E-21	5.061E-21	8.149E-21
562.63	7.205E-25	2.029E-23	1.320E-22	7.387E-22	2.529E-21	4.882E-21
617.59	8.772E-25	7.402E-24	5.992E-23	2.667E-22	1.180E-21	2.770E-21
727.51		2.784E-25	2.417E-23	6.278E-23	2.391E-22	7.663E-22
837.43		2.425E-25	1.169E-23	1.715E-23	5.782E-23	1.914E-22
947.35			2.487E-24	6.999E-24	1.610E-23	5.146E-23
1057.27			1.156E-24	4.474E-24	7.647E-24	1.458E-23

Reference: These data were taken from J. B. Crooks and M. E. Rudd, Phys. Rev. A 3, 1628 (1974).

Tabular Data I-2.B-13. Single differential cross section (secondary electron spectra) for $H^{+} + N_2$ collisions (units of cm^2/eV).

Proton Energy = 300 keV

ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)
0.	1.000-18	2.	2.641-18	4.	1.278-18	6.	1.340-18	8.	1.555-18	10.	1.638-18
12.	1.640-18	14.	1.675-18	16.	1.547-18	18.	1.327-18	20.	1.218-18	22.	1.040-18
24.	9.132-19	26.	8.450-19	28.	7.409-19	30.	6.808-19	32.	6.353-19	34.	5.815-19
36.	5.350-19	38.	5.088-19	40.	4.586-19	42.	4.292-19	44.	3.942-19	46.	3.852-19
48.	3.405-19	50.	3.138-19	52.	3.012-19	54.	2.790-19	56.	2.673-19	58.	2.480-19
60.	2.306-19	62.	2.242-19	64.	2.054-19	66.	2.043-19	68.	1.866-19	70.	1.811-19
72.	1.711-19	74.	1.626-19	76.	1.588-19	78.	1.416-19	80.	1.464-19	82.	1.369-19
84.	1.284-19	86.	1.270-19	87.	1.148-19	89.	1.133-19	91.	1.106-19	93.	1.050-19
95.	9.798-20	97.	9.637-20	99.	9.105-20	101.	8.812-20	103.	8.578-20	105.	8.359-20
107.	7.868-20	109.	7.755-20	111.	7.632-20	113.	7.451-20	115.	6.688-20	117.	6.674-20
119.	7.024-20	121.	6.183-20	123.	6.139-20	125.	5.763-20	127.	5.712-20	129.	5.703-20
131.	5.525-20	133.	5.170-20	135.	5.188-20	137.	5.132-20	139.	5.009-20	141.	4.666-20
143.	4.060-20	145.	4.564-20	147.	4.636-20	149.	4.246-20	151.	4.246-20	153.	4.012-20
155.	4.060-20	157.	3.835-20	159.	3.910-20	161.	3.748-20	163.	3.783-20	165.	3.614-20
167.	3.409-20	169.	3.360-20	171.	3.220-20	173.	3.198-20	175.	3.084-20	177.	3.211-20
179.	3.095-20	181.	2.861-20	183.	2.758-20	185.	2.733-20	187.	2.848-20	189.	2.770-20
191.	2.634-20	193.	2.574-20	195.	2.567-20	197.	2.462-20	199.	2.437-20	201.	2.448-20
203.	2.368-20	205.	2.383-20	207.	2.331-20	209.	2.237-20	211.	2.186-20	213.	2.142-20
215.	2.127-20	217.	2.071-20	219.	2.083-20	221.	1.933-20	223.	1.973-20	225.	1.804-20
227.	1.976-20	229.	1.793-20	231.	1.732-20	233.	1.820-20	235.	1.714-20	237.	1.769-20
239.	1.737-20	241.	1.784-20	243.	1.736-20	245.	1.582-20	247.	1.564-20	249.	1.549-20
251.	1.545-20	253.	1.571-20	255.	1.594-20	257.	1.479-20	259.	1.481-20	260.	1.441-20
262.	1.413-20	264.	1.409-20	266.	1.491-20	268.	1.556-20	270.	1.438-20	272.	1.413-20
274.	1.308-20	276.	1.326-20	278.	1.372-20	280.	1.204-20	282.	1.403-20	284.	1.272-20
286.	1.276-20	288.	1.306-20	290.	1.297-20	292.	1.224-20	294.	1.172-20	296.	1.211-20
298.	1.197-20	300.	1.128-20	302.	1.120-20	304.	1.183-20	306.	1.164-20	308.	1.232-20
310.	1.206-20	312.	1.195-20	314.	1.275-20	316.	1.236-20	319.	1.231-20	320.	1.207-20
322.	1.274-20	324.	1.349-20	326.	1.361-20	328.	1.337-20	330.	1.361-20	332.	1.543-20
334.	1.535-20	336.	1.651-20	338.	1.730-20	340.	1.661-20	342.	1.985-20	344.	2.042-20
346.	2.131-20	348.	2.296-20	350.	2.443-20	352.	2.443-20	354.	2.527-20	356.	2.454-20
358.	2.571-20	360.	2.546-20	362.	2.469-20	364.	2.705-20	366.	2.777-20	368.	2.966-20
370.	2.822-20	372.	2.746-20	374.	2.668-20	376.	2.539-20	378.	2.363-20	380.	2.007-20
382.	1.670-20	384.	1.562-20	386.	1.329-20	388.	1.119-20	390.	1.021-20	392.	9.875-21
394.	8.998-21	396.	8.905-21	398.	7.441-21	400.	7.047-21	402.	6.360-21	404.	5.792-21
406.	6.290-21	412.	5.748-21	422.	5.635-21	432.	5.297-21	441.	5.014-21	451.	4.972-21
463.	4.556-21	477.	4.354-21	491.	4.187-21	505.	3.868-21	519.	3.600-21	533.	3.382-21
547.	3.330-21	561.	3.152-21	575.	2.954-21	589.	2.818-21				

ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)
603.	2.816-21	618.	2.594-21	636.	2.428-21	654.	2.253-21	672.	2.149-21	690.	2.166-21
708.	1.874-21	726.	1.858-21	744.	1.805-21	762.	1.720-21	781.	1.521-21	803.	1.453-21
825.	1.372-21	847.	1.279-21	869.	1.259-21	891.	1.109-21	913.	1.112-21	937.	1.044-21
962.	1.002-21	988.	9.480-22	1014.	8.531-22	1040.	8.592-22	1066.	8.333-22	1094.	7.794-22
1124.	7.443-22	1153.	6.988-22	1183.	6.718-22	1213.	6.090-22	1245.	5.917-22	1279.	5.540-22
1312.	5.345-22	1346.	5.204-22	1380.	4.797-22	1416.	4.523-22	1454.	4.306-22	1491.	4.165-22
1529.	4.014-22	1569.	3.778-22	1611.	3.618-22	1652.	3.508-22	1696.	3.139-22	1742.	3.277-22
1788.	3.339-22	1833.	2.946-22	1881.	2.833-22	1931.	2.626-22	1981.	2.378-22	2032.	2.382-22
2086.	2.233-22	2140.	2.176-22	2195.	2.000-22	2253.	1.998-22	2313.	1.886-22	2374.	1.751-22
2436.	1.688-22	2500.	1.643-22	2565.	1.603-22	2633.	1.471-22	2702.	1.498-22	2774.	1.494-22
2848.	1.474-22	2921.	1.293-22	2997.	1.108-22	3074.	1.102-22	3154.	8.987-23	3237.	7.450-23
3323.	5.656-23	3410.	4.072-23	3500.	2.717-23	3591.	1.574-23	3685.	7.285-24	3780.	1.586-24

Note: Energy is secondary electron energy in eV.

Reference: These data were taken from L. H. Toburen, Phys. Rev. A 3, 216 (1971).

Tabular Data I-2.B-14. Single differential cross section (secondary electron spectra) for $H^{+} + N_2$ collisions (units of cm^2/eV).

Proton Energy = 500 keV

ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)
0.	1.000-18	2.	5.973-18	4.	3.111-18	6.	2.994-18	8.	2.730-18	10.	2.576-18
12.	2.337-18	14.	2.051-18	16.	1.788-18	18.	1.550-18	20.	1.313-18	22.	1.171-18
24.	1.001-18	26.	8.977-19	28.	7.848-19	30.	7.488-19	32.	6.818-19	34.	6.229-19
36.	5.767-19	38.	5.072-19	40.	5.008-19	42.	4.503-19	44.	4.131-19	46.	3.836-19
48.	3.550-19	50.	3.305-19	52.	3.198-19	54.	2.940-19	56.	2.780-19	58.	2.528-19
60.	2.495-19	62.	2.373-19	64.	2.152-19	66.	2.086-19	68.	1.963-19	70.	1.890-19
72.	1.769-19	74.	1.710-19	76.	1.618-19	78.	1.494-19	80.	1.380-19	82.	1.439-19
84.	1.312-19	86.	1.347-19	87.	1.194-19	89.	1.169-19	91.	1.134-19	93.	1.080-19
95.	1.017-19	97.	9.756-20	99.	9.761-20	101.	9.536-20	103.	9.014-20	105.	8.200-20
107.	7.923-20	109.	7.563-20	111.	8.005-20	113.	7.488-20	115.	7.578-20	117.	6.591-20
119.	6.601-20	121.	6.359-20	123.	6.333-20	125.	6.097-20	127.	6.239-20	129.	5.668-20
131.	5.686-20	133.	5.695-20	135.	5.459-20	137.	5.187-20	139.	5.080-20	141.	4.692-20
143.	4.514-20	145.	4.532-20	147.	4.668-20	149.	4.317-20	151.	4.241-20	153.	3.944-20
155.	3.915-20	157.	4.035-20	159.	3.858-20	161.	3.769-20	163.	3.507-20	165.	3.716-20
167.	3.804-20	169.	3.383-20	171.	3.338-20	173.	3.263-20	175.	3.117-20	177.	3.070-20
179.	3.147-20	181.	3.039-20	183.	2.962-20	185.	2.890-20	187.	2.583-20	189.	2.783-20
191.	2.606-20	193.	2.751-20	195.	2.581-20	197.	2.684-20	199.	2.420-20	201.	2.431-20
203.	2.293-20	205.	2.262-20	207.	2.193-20	209.	2.317-20	211.	2.191-20	213.	2.088-20
215.	2.339-20	217.	2.215-20	219.	1.974-20	221.	2.034-20	223.	2.097-20	225.	1.964-20
227.	1.900-20	229.	1.838-20	231.	1.803-20	233.	1.973-20	235.	1.746-20	237.	1.872-20
239.	1.697-20	241.	1.745-20	243.	1.755-20	245.	1.705-20	247.	1.600-20	249.	1.517-20
251.	1.571-20	253.	1.654-20	255.	1.589-20	257.	1.565-20	259.	1.582-20	260.	1.524-20
262.	1.461-20	264.	1.467-20	266.	1.393-20	268.	1.504-20	270.	1.516-20	272.	1.399-20
274.	1.532-20	276.	1.499-20	278.	1.364-20	280.	1.364-20	282.	1.369-20	284.	1.300-20
286.	1.299-20	288.	1.332-20	290.	1.228-20	292.	1.220-20	294.	1.199-20	296.	1.209-20
298.	1.185-20	300.	1.271-20	302.	1.302-20	304.	1.262-20	306.	1.281-20	308.	1.381-20
310.	1.209-20	312.	1.215-20	314.	1.353-20	316.	1.325-20	318.	1.339-20	320.	1.330-20
322.	1.313-20	324.	1.435-20	326.	1.426-20	328.	1.530-20	330.	1.602-20	332.	1.568-20
334.	1.703-20	336.	1.742-20	338.	1.810-20	340.	1.872-20	342.	1.919-20	344.	2.000-20
346.	2.116-20	348.	2.223-20	350.	2.210-20	352.	2.311-20	354.	2.311-20	356.	2.371-20
358.	2.533-20	360.	2.568-20	362.	2.531-20	364.	2.457-20	366.	2.352-20	368.	2.197-20
370.	2.219-20	372.	2.240-20	374.	2.086-20	376.	1.919-20	378.	1.823-20	380.	1.431-20
382.	1.337-20	384.	1.229-20	386.	1.119-20	388.	1.107-20	390.	1.034-20	392.	1.039-20
394.	9.490-21	396.	9.576-21	398.	8.557-21	400.	8.039-21	402.	7.927-21	404.	7.210-21
406.	7.233-21	412.	6.452-21	422.	5.577-21	432.	5.581-21	441.	5.283-21	451.	4.868-21
463.	4.799-21	477.	4.431-21	491.	4.067-21	505.	3.815-21	519.	3.717-21	533.	3.465-21
547.	3.201-21	561.	3.305-21	575.	2.901-21	589.	2.797-21	603.	2.590-21	618.	2.620-21
636.	2.387-21	654.	2.274-21	672.	2.163-21	690.	2.059-21	708.	2.049-21	726.	1.824-21
744.	1.044-21	762.	1.710-21	781.	1.623-21	803.	1.559-21	825.	1.516-21	847.	1.403-21
869.	1.367-21	891.	1.317-21	913.	1.196-21	937.	1.130-21	962.	1.066-21	988.	1.003-21
1014.	9.261-22										

ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)
1040.	9.132-22	1066.	8.502-22	1094.	7.697-22	1124.	7.421-22	1153.	6.561-22	1183.	6.329-22
1213.	6.063-22	1245.	5.409-22	1279.	5.326-22	1312.	4.937-22	1346.	4.638-22	1380.	4.281-22
1416.	4.217-22	1454.	3.699-22	1491.	3.550-22	1529.	3.594-22	1569.	3.448-22	1611.	3.311-22
1652.	3.290-22	1696.	3.226-22	1742.	3.113-22	1788.	2.727-22	1833.	2.868-22	1881.	2.620-22
1931.	2.590-22	1981.	2.495-22	2032.	2.452-22	2086.	2.388-22	2140.	2.214-22	2195.	2.125-22
2253.	2.134-22	2313.	1.943-22	2374.	1.803-22	2436.	1.767-22	2500.	1.625-22	2565.	1.467-22
2633.	1.370-22	2702.	1.093-22	2774.	9.625-23	2848.	7.675-23	2921.	5.400-23	2997.	2.460-23

Note: Energy is secondary electron energy in eV.

Reference: These data were taken from L. H. Toburen, Phys. Rev. A 3, 216 (1971).

Tabular Data I-2.B-15. Single differential cross section (secondary electron spectra) for $H^+ + N_2$ collisions (units of cm^2/eV).

Proton Energy = 1 MeV

ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)
0.	4.500-18	2.	4.996-18	4.	6.175-18	6.	5.252-18	8.	4.440-18	10.	4.092-18
12.	3.527-18	14.	2.895-18	16.	2.461-18	18.	1.994-18	20.	1.657-18	22.	1.459-18
24.	1.278-18	26.	1.178-18	28.	1.071-18	30.	1.009-18	32.	8.843-19	[illegible]	8.449-19
36.	7.697-19	38.	7.371-19	40.	6.776-19	42.	6.351-19	44.	5.890-19	[illegible]	5.413-19
47.	4.971-19	49.	4.706-19	51.	4.330-19	53.	4.116-19	55.	3.941-19	57.	3.829-19
59.	3.638-19	61.	3.384-19	63.	3.152-19	65.	2.981-19	67.	2.889-19	69.	2.784-19
71.	2.634-19	73.	2.485-19	75.	2.362-19	77.	2.196-19	79.	2.209-19	81.	2.076-19
83.	1.994-19	85.	1.924-19	87.	1.862-19	89.	1.701-19	91.	1.670-19	93.	1.545-19
95.	1.538-19	97.	1.521-19	99.	1.408-19	101.	1.460-19	103.	1.374-19	105.	1.354-19
107.	1.287-19	109.	1.228-19	111.	1.210-19	113.	1.143-19	115.	1.116-19	117.	1.069-19
119.	1.068-19	121.	9.020-20	123.	9.761-20	125.	9.931-20	127.	9.540-20	129.	9.392-20
131.	8.720-20	133.	8.695-20	135.	8.536-20	137.	7.946-20	139.	8.129-20	140.	7.384-20
142.	7.734-20	144.	7.254-20	146.	7.171-20	148.	6.863-20	150.	6.730-20	152.	6.533-20
154.	6.422-20	156.	6.238-20	158.	6.013-20	160.	6.028-20	162.	5.757-20	164.	5.864-20
166.	5.400-20	168.	5.573-20	170.	5.510-20	172.	5.327-20	174.	4.972-20	176.	5.032-20
178.	5.094-20	180.	4.727-20	182.	4.714-20	184.	4.737-20	186.	4.269-20	188.	4.527-20
190.	4.482-20	192.	4.423-20	194.	4.255-20	196.	4.018-20	198.	4.013-20	200.	4.048-20
202.	3.844-20	204.	3.770-20	206.	3.875-20	208.	3.683-20	210.	3.499-20	212.	3.561-20
214.	3.457-20	216.	3.614-20	218.	3.446-20	220.	3.375-20	222.	3.389-20	224.	3.120-20
226.	3.304-20	228.	3.215-20	230.	3.134-20	232.	3.107-20	233.	3.035-20	235.	2.830-20
237.	2.902-20	239.	2.933-20	241.	2.775-20	243.	2.697-20	245.	2.636-20	247.	2.739-20
249.	2.573-20	251.	2.497-20	253.	2.590-20	255.	2.637-20	257.	2.578-20	259.	2.665-20
261.	2.453-20	263.	2.412-20	265.	2.430-20	267.	2.311-20	269.	2.347-20	271.	2.248-20
273.	2.285-20	275.	2.274-20	277.	2.189-20	279.	2.181-20	281.	2.134-20	283.	2.197-20
285.	2.045-20	287.	2.187-20	289.	2.033-20	291.	2.026-20	293.	2.091-20	295.	2.038-20
297.	1.917-20	299.	1.966-20	301.	1.974-20	303.	2.017-20	305.	1.993-20	307.	1.843-20
309.	1.999-20	311.	1.869-20	313.	1.860-20	315.	1.856-20	317.	1.998-20	319.	2.046-20
321.	2.061-20	323.	2.156-20	325.	2.122-20	327.	2.213-20	328.	2.092-20	330.	2.222-20
332.	2.165-20	334.	2.319-20	336.	2.448-20	338.	2.522-20	340.	2.745-20	342.	2.915-20
344.	2.955-20	346.	2.947-20	348.	3.057-20	350.	3.135-20	352.	3.031-20	354.	3.094-20
356.	3.178-20	358.	3.138-20	360.	3.231-20	362.	3.375-20	364.	3.441-20	366.	3.607-20
368.	3.652-20	370.	3.527-20	372.	3.447-20	374.	3.130-20	376.	2.911-20	378.	2.494-20
380.	2.180-20	382.	1.969-20	384.	1.707-20	386.	1.557-20	388.	1.551-20	390.	1.369-20
392.	1.250-20	394.	1.220-20	396.	1.177-20	398.	1.076-20	400.	1.052-20	402.	1.012-20
404.	1.007-20	410.	9.377-21	420.	8.944-21	429.	7.899-21	439.	8.254-21	449.	7.594-21
461.	7.387-21	475.	6.783-21	489.	6.297-21	503.	5.900-21	516.	5.694-21	530.	5.257-21
544.	5.063-21	558.	4.629-21	572.	4.631-21	586.	4.291-21	600.	4.205-21	615.	4.047-21
633.	3.010-21	651.	3.561-21	669.	3.473-21	687.	3.233-21	704.	3.156-21	722.	2.941-21
740.	2.836-21	758.	2.673-21	778.	2.615-21	799.	2.515-21	821.	2.331-21	843.	2.190-21
865.	2.113-21	887.	2.042-21	908.	1.886-21	932.	1.750-21				

ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)
958.	1.618-21	983.	1.565-21	1009.	1.449-21	1035.	1.372-21	1061.	1.268-21	1088.	1.230-21
1118.	1.164-21	1148.	1.097-21	1177.	1.072-21	1207.	9.644-22	1239.	9.219-22	1272.	8.341-22
1306.	8.246-22	1340.	7.763-22	1373.	7.279-22	1409.	7.130-22	1447.	6.733-22	1484.	6.543-22
1522.	6.266-22	1561.	6.249-22	1603.	5.705-22	1644.	5.519-22	1688.	5.375-22	1733.	4.976-22
1779.	4.651-22	1824.	4.089-22	1872.	3.615-22	1921.	3.265-22	1971.	2.949-22	2022.	2.389-22
2076.	1.977-22	2129.	1.604-22	2185.	1.271-22	2242.	9.825-23	2301.	7.187-23	2363.	5.040-23
2424.	1.563-23										

Note: Energy is secondary electron energy in eV.

Reference: These data were taken from L. H. Toburen, Phys. Rev. A 3, 216 (1971).

Tabular Data I-2.B-16. Single differential cross section (secondary electron spectra) for $H^+ + N_2$ collisions (units of cm^2/eV).

Proton Energy = 1.4 MeV

ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)
0.	4.500-18	2.	4.534-18	4.	3.285-18	6.	3.805-18	8.	4.153-18	10.	4.335-18
12.	4.189-18	14.	3.953-18	16.	3.523-18	18.	3.185-18	20.	2.780-18	22.	2.532-18
24.	2.213-18	26.	2.058-18	28.	1.905-18	30.	1.753-18	32.	1.642-18	34.	1.506-18
36.	1.426-18	38.	1.327-18	40.	1.232-18	42.	1.181-18	44.	1.095-18	46.	1.024-18
47.	9.649-19	49.	9.173-19	51.	8.402-19	53.	8.036-19	55.	7.734-19	57.	7.037-19
59.	6.961-19	61.	6.618-19	63.	6.318-19	65.	5.861-19	67.	5.585-19	69.	5.459-19
71.	5.090-19	73.	4.880-19	75.	4.692-19	77.	4.452-19	79.	4.269-19	81.	4.193-19
83.	4.025-19	85.	3.857-19	87.	3.785-19	89.	3.555-19	91.	3.436-19	93.	3.241-19
95.	3.130-19	97.	3.166-19	99.	2.982-19	101.	2.899-19	103.	2.824-19	105.	2.735-19
107.	2.633-19	109.	2.513-19	111.	2.508-19	113.	2.396-19	115.	2.346-19	117.	2.257-19
119.	2.135-19	121.	2.094-19	123.	2.016-19	125.	2.034-19	127.	1.928-19	129.	1.825-19
131.	1.772-19	133.	1.730-19	135.	1.717-19	137.	1.680-19	139.	1.657-19	140.	1.612-19
142.	1.583-19	144.	1.496-19	146.	1.463-19	148.	1.450-19	150.	1.479-19	152.	1.362-19
154.	1.315-19	156.	1.304-19	158.	1.309-19	160.	1.252-19	162.	1.223-19	164.	1.180-19
166.	1.190-19	168.	1.160-19	170.	1.121-19	172.	1.107-19	174.	1.066-19	176.	1.042-19
178.	1.040-19	180.	9.765-20	182.	9.469-20	184.	9.637-20	186.	9.628-20	188.	9.352-20
190.	9.294-20	192.	9.148-20	194.	8.729-20	196.	8.611-20	198.	8.356-20	200.	8.358-20
202.	7.983-20	204.	7.939-20	206.	7.752-20	208.	7.535-20	210.	7.699-20	212.	7.628-20
214.	7.311-20	216.	7.226-20	218.	6.930-20	220.	6.645-20	222.	6.895-20	224.	6.665-20
226.	6.526-20	228.	6.288-20	230.	6.430-20	232.	6.407-20	233.	6.214-20	235.	5.962-20
237.	5.789-20	239.	5.536-20	241.	5.583-20	243.	5.622-20	245.	5.409-20	247.	5.272-20
249.	5.347-20	251.	5.333-20	253.	5.199-20	255.	5.223-20	257.	5.084-20	259.	5.056-20
261.	4.723-20	263.	4.936-20	265.	4.764-20	267.	4.551-20	269.	4.410-20	271.	4.631-20
273.	4.556-20	275.	4.299-20	277.	4.308-20	279.	4.137-20	281.	4.162-20	283.	4.229-20
285.	4.036-20	287.	3.986-20	289.	3.891-20	291.	4.088-20	293.	3.819-20	295.	3.881-20
297.	3.865-20	299.	3.699-20	301.	3.723-20	303.	3.608-20	305.	3.533-20	307.	3.465-20
309.	3.555-20	311.	3.506-20	313.	3.596-20	315.	3.439-20	317.	3.470-20	319.	3.404-20
321.	3.562-20	323.	3.519-20	325.	3.494-20	327.	3.530-20	328.	3.443-20	330.	3.417-20
332.	3.573-20	334.	3.586-20	336.	3.700-20	338.	3.742-20	340.	3.955-20	342.	4.035-20
344.	4.002-20	346.	4.198-20	348.	4.236-20	350.	4.207-20	352.	4.251-20	354.	4.121-20
356.	4.201-20	358.	4.121-20	360.	4.225-20	362.	4.214-20	364.	4.351-20	366.	4.338-20
368.	4.279-20	370.	4.237-20	372.	4.105-20	374.	4.040-20	376.	3.713-20	378.	3.447-20
380.	3.077-20	382.	2.789-20	384.	2.713-20	386.	2.539-20	388.	2.327-20	390.	2.269-20
392.	2.157-20	394.	1.972-20	396.	2.023-20	398.	2.004-20	400.	1.942-20	402.	1.848-20
404.	1.856-20	410.	1.785-20	420.	1.698-20	429.	1.600-20	439.	1.495-20	449.	1.437-20
461.	1.369-20	475.	1.239-20	489.	1.167-20	503.	1.098-20	516.	1.007-20	530.	9.615-21
544.	8.989-21	558.	8.459-21	572.	7.912-21	586.	7.498-21	600.	6.860-21	615.	6.536-21
633.	6.275-21	651.	5.876-21	669.	5.540-21	687.	5.304-21	704.	4.941-21	722.	4.749-21
740.	4.360-21	758.	4.174-21	778.	3.913-21	799.	3.670-21	821.	3.182-21	843.	2.964-21
865.	2.663-21	887.	2.352-21	908.	1.956-21	932.	1.755-21	958.	1.466-21	983.	1.229-21
1009.	1.001-21	1035.	8.305-22	1061.	6.747-22	1089.	5.298-22	1118.	3.784-22	1148.	2.826-22
1177.	1.477-22	1207.	1.326-22	1239.	8.249-23	1272.	3.622-23				

Note: Energy is secondary electron energy in eV.

Reference: These data were taken from L.H. Toburen, Phys. Rev. A 3, 216 (1971).

Tabular Data I-2.B-17. Single differential cross sections (secondary electron spectra) for $H^+ + N_2$ collisions (units of cm^2/eV).

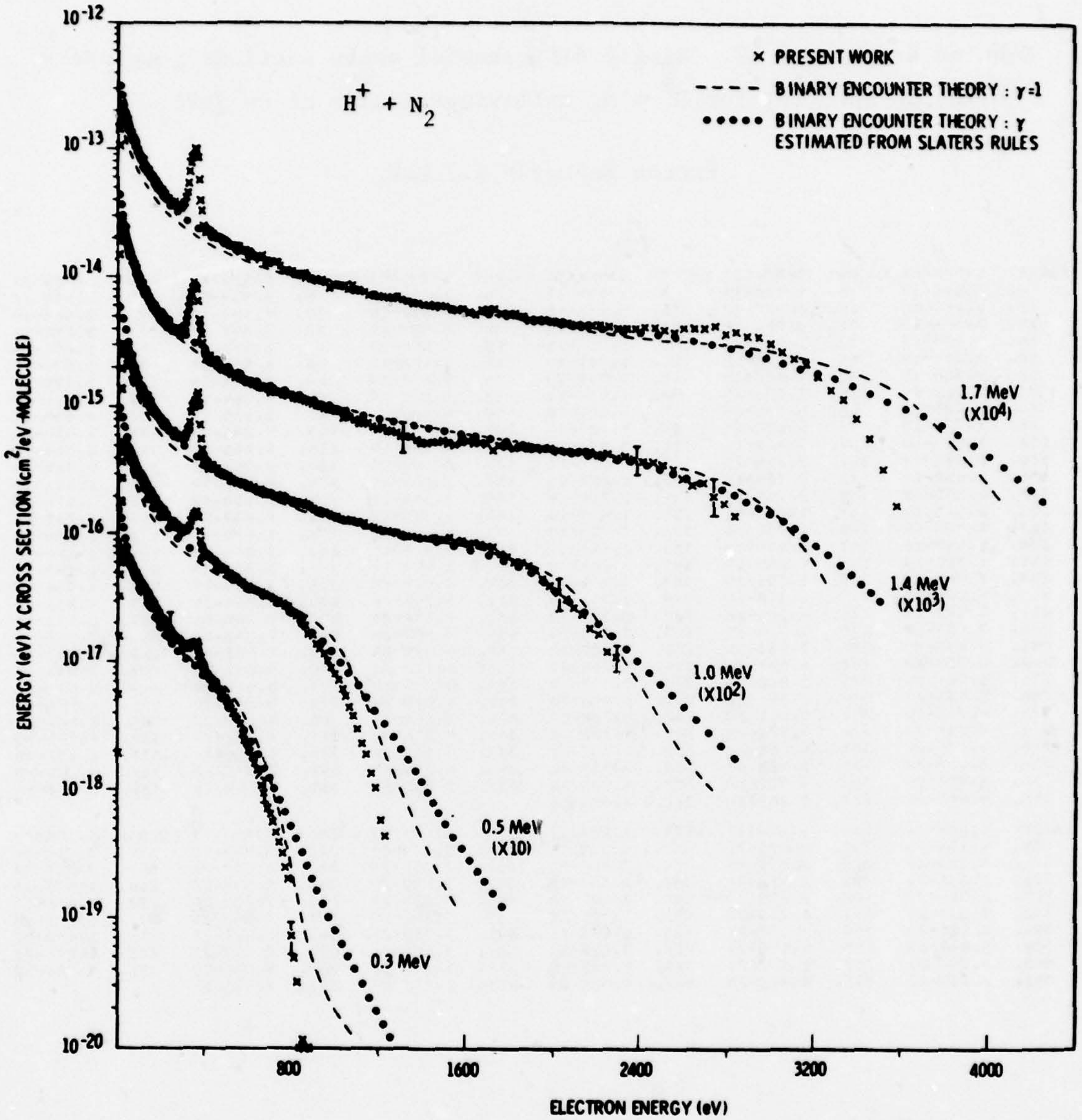
Proton Energy = 1.7 MeV

ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)
0.	1.200-17	2.	1.160-17	4.	1.199-17	6.	1.051-17	8.	8.937-18	10.	7.919-18
12.	6.981-18	14.	5.907-18	16.	5.287-18	18.	4.577-18	20.	4.153-18	22.	3.629-18
24.	3.246-18	26.	2.861-18	28.	2.669-18	30.	2.509-18	32.	2.341-18	34.	2.242-18
36.	2.058-18	38.	1.884-18	40.	1.721-18	42.	1.654-18	44.	1.558-18	46.	1.452-18
48.	1.374-18	50.	1.279-18	52.	1.241-18	54.	1.188-18	56.	1.115-18	58.	1.070-18
60.	9.950-19	62.	9.485-19	64.	9.339-19	66.	8.632-19	68.	8.644-19	70.	8.106-19
72.	7.522-19	74.	7.358-19	76.	7.019-19	78.	6.829-19	80.	6.364-19	82.	6.311-19
84.	6.029-19	86.	5.906-19	87.	5.665-19	89.	5.400-19	91.	5.135-19	93.	4.955-19
95.	4.741-19	97.	4.652-19	99.	4.487-19	101.	4.257-19	103.	4.288-19	105.	3.939-19
107.	3.897-19	109.	3.814-19	111.	3.822-19	113.	3.639-19	115.	3.440-19	117.	3.379-19
119.	3.291-19	121.	3.258-19	123.	3.150-19	125.	3.005-19	127.	2.955-19	129.	2.864-19
131.	2.652-19	133.	2.730-19	135.	2.607-19	137.	2.601-19	139.	2.536-19	141.	2.405-19
143.	2.376-19	145.	2.268-19	147.	2.284-19	149.	2.261-19	151.	2.020-19	153.	2.072-19
155.	2.019-19	157.	1.974-19	159.	1.925-19	161.	1.936-19	163.	1.807-19	165.	1.755-19
167.	1.694-19	169.	1.750-19	171.	1.706-19	173.	1.594-19	175.	1.575-19	177.	1.550-19
179.	1.497-19	181.	1.469-19	183.	1.441-19	185.	1.415-19	187.	1.344-19	189.	1.291-19
191.	1.322-19	193.	1.265-19	195.	1.280-19	197.	1.249-19	199.	1.201-19	201.	1.147-19
203.	1.049-19	205.	1.101-19	207.	1.106-19	209.	1.070-19	211.	1.049-19	213.	1.030-19
215.	1.004-19	217.	1.010-19	219.	1.011-19	221.	9.794-20	223.	9.354-20	225.	9.286-20
227.	9.241-20	229.	9.394-20	231.	8.655-20	233.	8.792-20	235.	8.100-20	237.	8.672-20
239.	7.933-20	241.	7.776-20	243.	7.835-20	245.	7.887-20	247.	7.862-20	249.	7.289-20
251.	7.498-20	253.	7.120-20	255.	7.022-20	257.	6.979-20	259.	7.003-20	260.	6.603-20
262.	6.517-20	264.	6.449-20	266.	6.216-20	268.	6.122-20	270.	5.878-20	272.	6.093-20
274.	5.944-20	276.	5.912-20	278.	5.699-20	280.	5.530-20	282.	5.616-20	284.	5.634-20
286.	5.533-20	288.	5.444-20	290.	5.206-20	292.	5.164-20	294.	5.239-20	296.	4.477-20
298.	4.705-20	300.	5.044-20	302.	4.779-20	304.	4.800-20	306.	4.542-20	308.	4.535-20
310.	4.339-20	312.	4.428-20	314.	4.302-20	316.	4.258-20	318.	4.267-20	320.	4.019-20
322.	4.125-20	324.	4.065-20	326.	4.191-20	328.	4.207-20	330.	4.159-20	332.	4.111-20
334.	3.938-20	336.	3.458-20	338.	3.959-20	340.	4.053-20	342.	3.975-20	344.	4.257-20
346.	3.912-20	348.	3.922-20	350.	4.149-20	352.	3.988-20	354.	4.129-20	356.	3.981-20
358.	4.045-20	360.	3.968-20	362.	4.050-20						

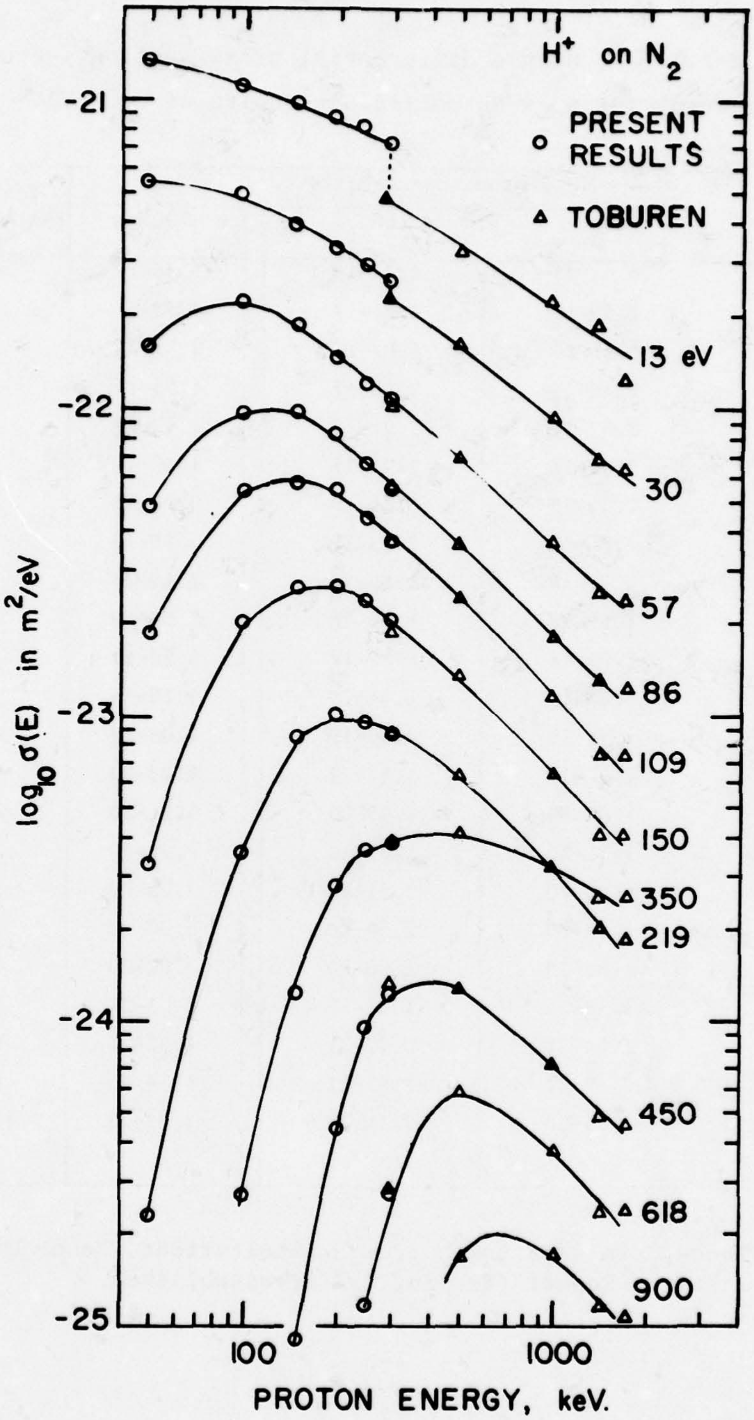
ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)	ENERGY	SIGMA(E)
364.	4.104-20	366.	3.825-20	368.	4.232-20	370.	4.127-20	372.	3.917-20	374.	3.758-20
376.	3.840-20	378.	3.430-20	380.	3.407-20	382.	3.352-20	384.	2.969-20	386.	2.910-20
388.	2.896-20	390.	2.868-20	392.	2.866-20	394.	2.609-20	396.	2.586-20	398.	2.535-20
400.	2.505-20	402.	2.477-20	404.	2.405-20	406.	2.270-20	412.	2.132-20	422.	1.964-20
432.	1.831-20	441.	1.719-20	451.	1.624-20	463.	1.466-20	477.	1.362-20	491.	1.246-20
505.	1.106-20	519.	9.944-21	533.	8.933-21	547.	7.736-21	561.	6.922-21	575.	6.106-21
588.	5.091-21	603.	4.170-21	618.	3.624-21	636.	3.100-21	654.	2.477-21	672.	2.020-21
690.	1.543-21	708.	1.203-21	726.	9.243-22	744.	7.716-22	762.	6.038-22	781.	4.329-22
803.	3.126-22	825.	8.818-23	847.	4.689-23	869.	1.270-23	891.	4.053-24		

Note: Energy is secondary electron energy in eV.

Reference: These data were taken from L.H. Toburen, Phys. Rev. A 3, 216 (1971).



Graphical Data I-2.B-18. Single differential cross section (secondary electron spectrum) for $H^+ + N_2$ collisions. These data were taken from L. H. Toburen, Phys. Rev. A 3, 216 (1971).



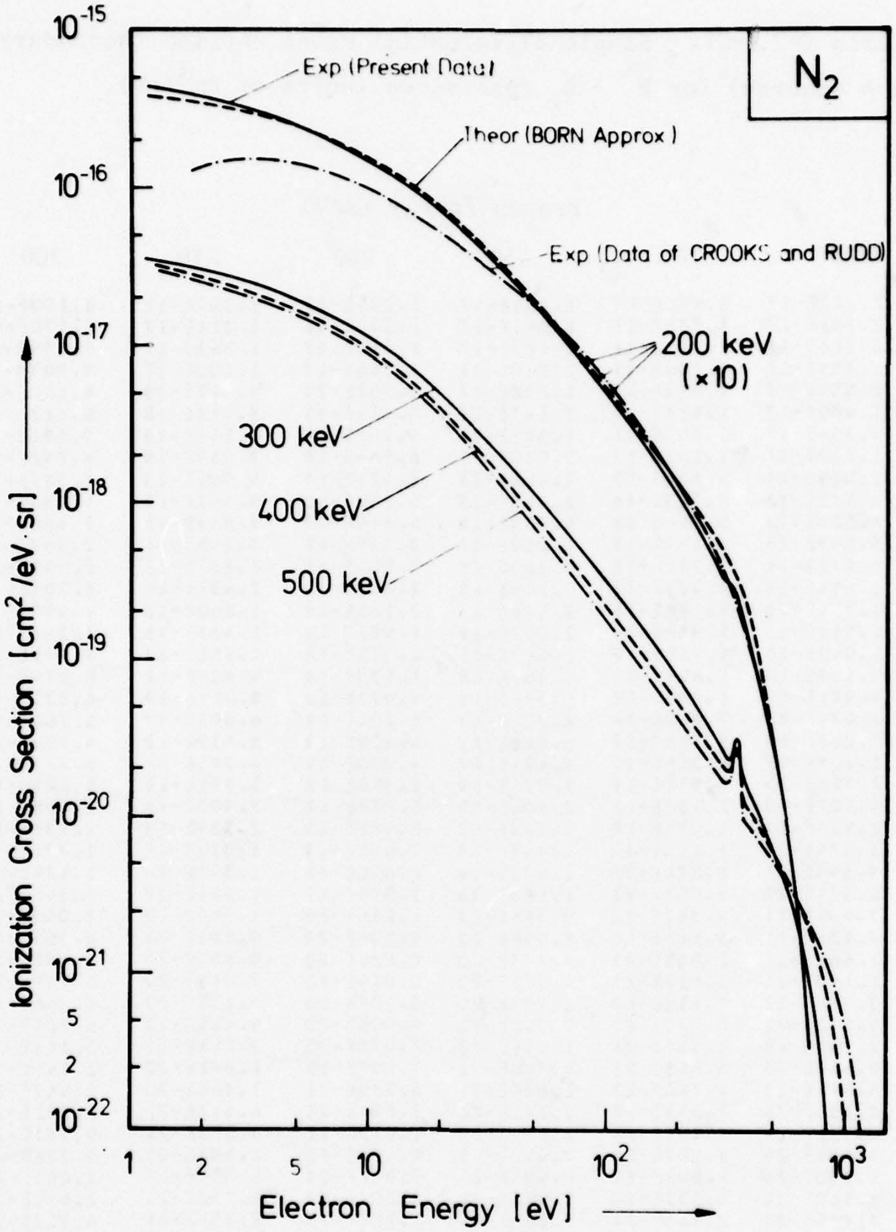
Graphical Data I-2.B-19. Single differential cross section (secondary electron spectrum) for $H^+ + N_2$ collisions.

These data were taken from J. B. Crooks and M. E. Rudd, Phys. Rev. A 3, 1628 (1971); present results are from that reference and "Toburen" is from L. H. Toburen, Phys. Rev. A 3, 216 (1971).

Tabular Data I-2.B-20. Single differential cross section (secondary electron spectra) for $H^+ + N_2$ collisions (units of cm^2/eV).

Electron Energy (eV)	Proton Energy (keV) 200	300	400	Electron Energy (eV)
0	6.44-17	4.74-17	3.38-17	0
2	7.59-17	6.34-17	4.77-17	2
4	5.16-17	4.02-17	2.81-17	4
6	3.48-17	2.68-17	1.95-17	6
8	2.52-17	1.91-17	1.42-17	8
10	2.04-17	1.45-17	1.08-17	10
20	7.54-18	5.16-18	3.88-18	20
30	3.85-18	2.63-18	1.93-18	30
40	2.37-18	1.55-18	1.13-18	40
50	1.59-18	1.02-18	7.51-19	50
64	1.02-18	6.77-19	5.50-19	60
80	6.68-19	4.41-19	3.28-19	80
104	3.91-19	2.60-19	2.08-19	100
144	1.92-19	1.34-19	9.23-20	150
184	1.09-19	7.95-20	5.11-20	200
224	7.17-20	5.57-10	7.36-20	250
264	4.62-20	3.71-20	2.05-20	300
304	2.96-20	2.59-20	1.38-20	350
344	1.89-20	1.90-20	1.02-20	400
400	9.18-21	1.31-20	6.01-21	500
504	1.64-21	6.77-21	3.92-21	600
600	2.39-22	2.91-21	1.14-21	800
800	3.55-23	9.74-22	1.15-22	1000

Reference: These data were taken from N. Stolterfoht, Hahn-Meitner Institut Report (Berlin, 1971), unpublished.



Graphical Data I-2.B-21. Single differential cross section (secondary electron spectrum) for $H^+ + N_2$ collisions. These data were taken from N. Stolterfoht, Z. Phys. 248, 92 (1971).

Tabular Data I-2.B-22. Single differential cross section (secondary electron spectra) for $H^+ + O_2$ collisions (units of cm^2/eV).

Electron Energy (eV)	Proton Energy (keV) 50	100	150	200	250	300
0.0	2.221E-17	1.446E-17	1.366E-17	1.293E-17	1.307E-17	1.190E-17
1.49	2.101E-17	1.726E-17	1.563E-17	1.376E-17	1.311E-17	1.170E-17
3.41	2.218E-17	2.213E-17	1.887E-17	1.518E-17	1.347E-17	1.196E-17
5.34	1.895E-17	1.790E-17	1.510E-17	1.258E-17	1.100E-17	9.903E-18
7.26	1.654E-17	1.493E-17	1.272E-17	1.082E-17	9.612E-18	8.682E-18
9.18	1.488E-17	1.326E-17	1.140E-17	9.955E-18	8.918E-18	8.112E-18
11.11	1.354E-17	1.200E-17	1.042E-17	9.197E-18	8.165E-18	7.392E-18
13.03	1.279E-17	1.107E-17	9.520E-18	8.564E-18	7.539E-18	6.737E-18
17.15	1.019E-17	8.676E-18	7.488E-18	6.623E-18	5.906E-18	5.383E-18
21.27	8.139E-18	7.023E-18	5.965E-18	5.298E-18	4.597E-18	4.230E-18
25.40	6.588E-18	5.844E-18	4.909E-18	4.344E-18	3.833E-18	3.485E-18
29.52	5.199E-18	5.149E-18	4.269E-18	3.739E-18	3.303E-18	2.988E-18
33.64	4.178E-18	4.581E-18	3.768E-18	3.262E-18	2.865E-18	2.557E-18
37.76	3.434E-18	4.083E-18	3.289E-18	2.856E-18	2.481E-18	2.205E-18
47.38	2.251E-18	3.148E-18	2.576E-18	2.165E-18	1.860E-18	1.630E-18
57.00	1.514E-18	2.349E-18	2.057E-18	1.587E-18	1.433E-18	1.247E-18
66.62	1.049E-18	1.728E-18	1.669E-18	1.375E-18	1.152E-18	9.971E-19
76.23	7.153E-19	1.307E-18	1.362E-18	1.150E-18	9.534E-19	8.174E-19
85.85	4.971E-19	1.004E-18	1.096E-18	9.672E-19	8.017E-19	6.825E-19
95.47	3.474E-19	7.863E-19	8.770E-19	8.201E-19	6.801E-19	5.760E-19
109.21	2.062E-19	5.628E-19	6.485E-19	6.400E-19	5.439E-19	4.599E-19
122.95	1.221E-19	4.068E-19	4.894E-19	4.899E-19	4.385E-19	3.723E-19
136.69	7.315E-20	2.978E-19	3.775E-19	3.849E-19	3.575E-19	3.087E-19
150.43	4.327E-20	2.180E-19	2.980E-19	3.073E-19	2.900E-19	2.575E-19
164.17	2.616E-20	1.574E-19	2.329E-19	2.462E-19	2.329E-19	2.135E-19
177.91	1.574E-20	1.136E-19	1.349E-19	2.001E-19	1.910E-19	1.771E-19
191.65	9.543E-21	8.274E-20	1.473E-19	1.650E-19	1.591E-19	1.474E-19
205.39	5.971E-21	6.003E-20	1.168E-19	1.378E-19	1.331E-19	1.245E-19
219.13	3.805E-21	4.367E-20	9.316E-20	1.146E-19	1.140E-19	1.060E-19
232.87	2.426E-21	3.121E-20	7.456E-20	9.606E-20	9.691E-20	9.065E-20
246.61	1.662E-21	2.218E-20	5.977E-20	8.025E-20	8.351E-20	7.898E-20
260.35	1.140E-21	1.512E-20	4.774E-20	6.849E-20	7.215E-20	6.897E-20
274.09	7.704E-22	1.117E-20	3.790E-20	5.792E-20	6.255E-20	6.046E-20
287.83	5.570E-22	8.339E-21	2.981E-20	4.905E-20	5.465E-20	5.364E-20
342.79	2.154E-22	2.161E-21	1.154E-20	2.470E-20	3.216E-20	3.343E-20
397.75	8.626E-23	6.558E-22	4.306E-21	1.197E-20	1.881E-20	2.165E-20
452.71	5.045E-23	3.780E-22	1.880E-21	6.320E-21	1.166E-20	1.549E-20
507.67	2.533E-23	2.043E-22	9.245E-22	3.193E-21	6.817E-21	1.052E-20
562.63	6.335E-24	4.497E-23	1.970E-22	1.039E-21	3.003E-21	5.491E-21
617.59	3.448E-24	2.083E-23	9.832E-23	4.487E-22	1.482E-21	3.228E-21
727.51	1.290E-24	6.892E-24	2.496E-23	9.911E-23	3.554E-22	1.006E-21
837.43	1.560E-24	4.375E-24	6.926E-24	3.297E-23	8.352E-23	2.670E-22
947.35	7.735E-25	2.560E-24	5.135E-24	1.209E-23	2.352E-23	6.757E-23
1057.27		1.959E-25	1.435E-24	4.033E-24	4.516E-24	2.636E-23

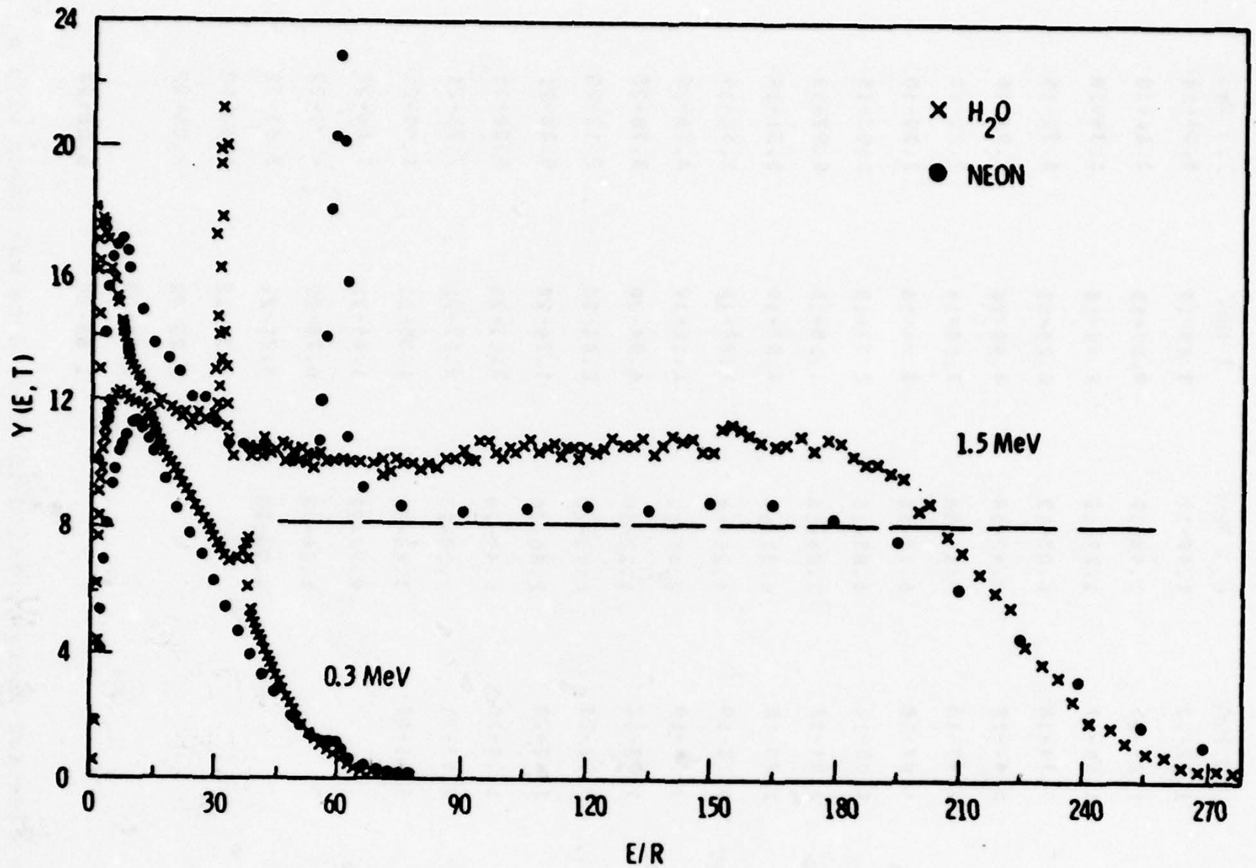
Reference: These data were taken from J.B. Crooks and M.E. Rudd, Phys. Rev. A 3, 1628 (1974).

Tabular Data I-2.B-23. Single differential cross section (secondary electron spectra) for $H^+ + H_2O$ collisions (units of cm^2/eV).

ENERGY (EV)	Proton Energy 0.3 MeV	0.5 MeV	1 MeV	1.5 MeV
0.0	1.22-17	1.49-17	8.89-18	3.32-18
1.0	1.25-17	1.48-17	9.07-18	3.36-18
1.9	1.16-17	1.27-17	8.45-18	3.36-18
3.8	9.74-18	1.03-17	6.26-18	3.25-18
5.8	8.44-18	8.42-18	4.48-18	3.04-18
7.7	7.47-18	7.16-18	3.69-18	2.71-18
9.6	6.84-18	5.74-18	3.06-18	2.39-18
15.0	5.03-18	3.83-18	2.01-18	1.83-18
25.0	3.04-18	2.28-18	1.15-18	9.97-19
50.0	1.20-18	8.33-19	4.07-19	3.31-19
75.0	6.23-19	4.25-19	1.97-19	1.55-19
100.0	3.66-19	2.43-19	1.11-19	8.58-20
150.0	1.73-19	1.12-19	4.94-20	3.78-20
200.0	9.22-20	6.43-20	2.80-20	2.12-20
300.0	3.62-20	2.80-20	1.26-20	9.36-21
400.0	1.70-20	1.49-20	7.03-21	5.28-21
500.0	9.53-21	1.20-20	8.07-21	7.25-21
750.0	5.43-22	3.40-21	1.85-21	1.40-21
1000.0		9.77-22	1.04-21	7.66-22
1250.0		1.26-22	6.78-22	4.97-22
1500.0		1.93-23	4.78-22	3.63-22
1750.0			3.38-22	2.66-22
2000.0			1.77-22	2.09-22
2500.0			1.07-23	
3000.0			1.83-25	6.28-23

Note: The low electron energy portion in these data was taken with a time-of-flight system and, thus, should be accurate down to about 1 eV.

Reference: These data were taken from L. H. Toburen and W. E. Wilson, J. Chem. Phys. 66, 5202 (1977).



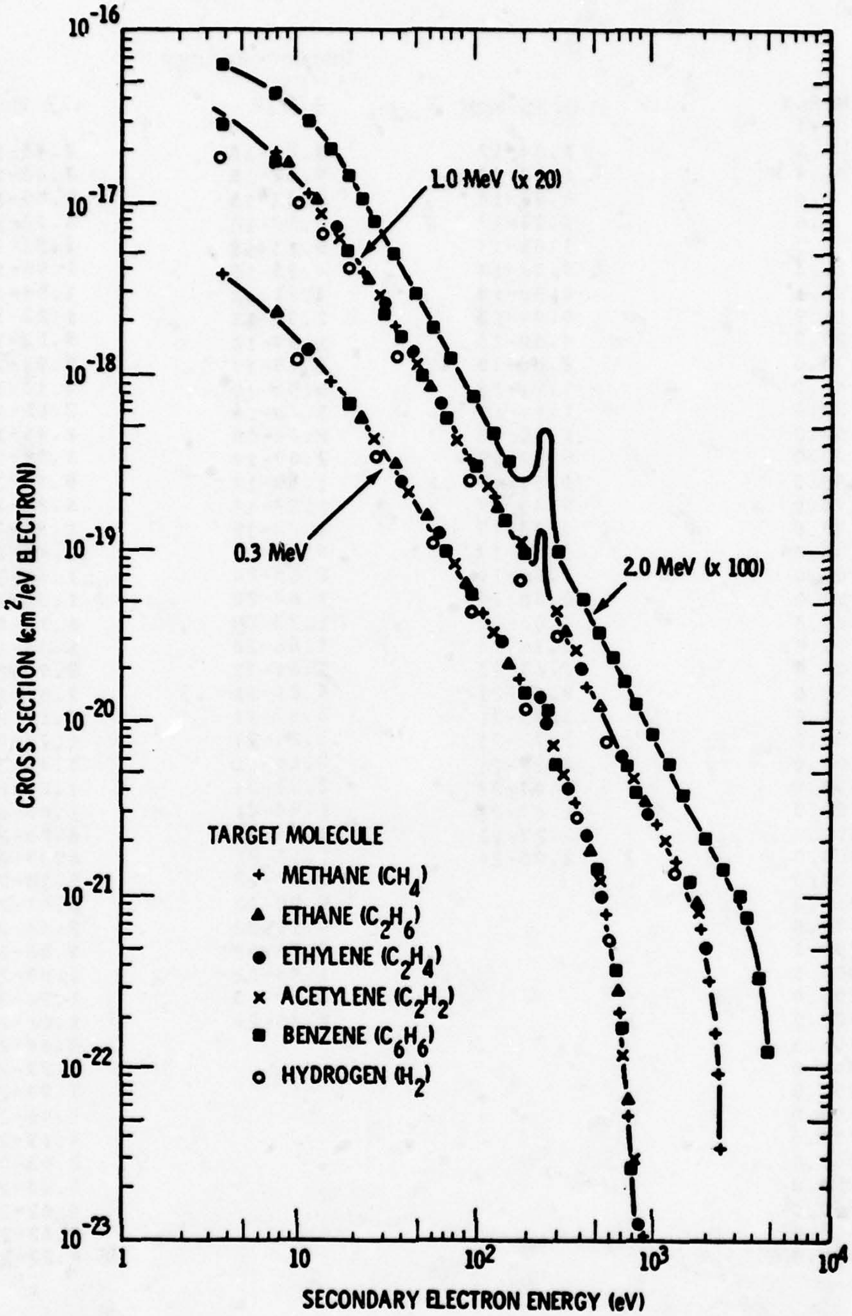
Graphical Data I-2.B-24. Single differential cross section (secondary electron spectrum) for $H^+ + H_2O$ and Ne collisions. These data were taken from L. H. Toburen and W. E. Wilson, J. Chem. Phys. 66, 5202 (1977). For an explanation of $Y(E,T)$ see the General Comments at the beginnina of this chapter.

Tabular Data I-2.B-25. Single differential cross section (secondary electron spectra) for $H^{+} + NH_3$ collisions (units of cm^2/eV).

ENERGY (EV)	Proton Energy 0.25 MeV	1 MeV	2 MeV
0.0	1.04-17	9.82-18	7.43-18
1.4	1.03-17	9.82-18	7.43-18
2.8	8.97-18	8.37-18	5.05-18
5.6	1.07-17	6.30-18	3.32-18
8.5	1.09-17	5.13-18	2.51-18
11.3	9.87-18	4.23-18	1.95-18
14.1	8.86-18	3.71-18	1.54-18
16.9	6.09-18	2.32-18	1.22-18
20.0	4.60-18	1.59-18	9.52-19
30.0	2.83-18	8.75-19	5.01-19
40.0	1.91-18	5.50-19	3.13-19
50.0	1.41-18	3.78-19	2.05-19
60.0	1.05-18	2.74-19	1.45-19
70.0	8.17-19	2.07-19	1.09-19
80.0	6.61-19	1.59-19	8.49-20
90.0	5.35-19	1.27-19	6.80-20
100.0	4.43-19	1.03-19	5.44-20
150.0	1.98-19	4.64-20	2.48-20
200.0	1.06-19	2.65-20	1.45-20
250.0	6.38-20	1.67-20	1.01-20
300.0	4.04-20	1.20-20	6.73-21
350.0	3.16-20	1.88-20	1.33-20
400.0	1.63-20	5.61-21	2.93-21
450.0	9.91-21	4.81-21	2.67-21
500.0	5.45-21	3.87-21	2.17-21
550.0	2.72-21	3.21-21	1.74-21
600.0	1.22-21	2.66-21	1.44-21
650.0	5.07-22	2.26-21	1.24-21
700.0	1.67-22	1.90-21	1.06-21
800.0	2.27-23	1.46-21	8.08-22
900.0	2.78-24	1.13-21	6.29-22
1000.0		9.17-22	5.10-22
1250.0		5.90-22	3.47-22
1500.0		4.10-22	2.44-22
1750.0		2.76-22	1.86-22
2000.0		1.44-22	1.49-22
2250.0		3.52-23	1.26-22
2500.0		2.45-24	1.01-22
2700.0			8.64-23
3000.0			6.79-23
3250.0			5.97-23
3500.0			4.96-23
3750.0			4.15-23
4000.0			2.93-23
4250.0			1.33-23
4500.0			4.62-24
4500.0			4.62-24
5000.0			4.22-25

Note: The low electron energy portion in these data was taken with a time-of-flight system and, thus, should be accurate down to about 1 eV.

Reference: These data were taken from D. J. Lynch, L. H. Toburen, and W. E. Wilson, J. Chem. Phys. 64, 2616 (1976).



Graphical Data I-2.B-26. Single differential cross section (secondary electron spectrum for H^+ + a number of gaseous molecules. These data were taken from W. E. Wilson and L. H. Toburen, Phys. Rev. A 11, 1303 (1975).

Tabular Data I-2.B-27. Single differential cross section (secondary electron spectra) for $H^+ + CH_4$ collisions (units of cm^2/eV).

ENERGY (EV)	Proton Energy 0.25 MeV	1 MeV	2 MeV
0.0	1.48-17	1.21-17	8.60-18
1.4	1.48-17	1.21-17	8.60-18
2.8	1.27-17	1.07-17	6.57-18
5.6	1.52-17	8.40-18	4.58-18
8.5	1.42-17	6.47-18	3.21-18
11.3	1.20-17	5.19-18	2.28-18
14.1	9.83-18	4.07-18	1.81-18
16.9	6.40-18	2.30-18	1.42-18
20.0	4.72-18	1.57-18	1.09-18
30.0	2.83-18	8.28-19	4.86-19
40.0	1.87-18	4.97-19	2.90-19
50.0	1.32-18	3.39-19	1.86-19
60.0	1.00-18	2.44-19	1.34-19
70.0	7.75-19	1.85-19	1.01-19
80.0	6.21-19	1.41-19	7.89-20
90.0	5.06-19	1.12-19	6.37-20
100.0	4.09-19	9.15-20	5.20-20
150.0	1.85-19	4.21-20	2.50-20
200.0	1.02-19	2.59-20	1.55-20
250.0	7.87-20	3.97-20	2.92-20
300.0	3.89-20	1.07-20	6.33-21
350.0	2.60-20	8.22-21	4.68-21
400.0	1.69-20	6.07-21	3.40-21
450.0	1.02-20	4.72-21	2.67-21
500.0	5.42-21	3.85-21	2.16-21
550.0	2.53-21	3.13-21	1.71-21
600.0	1.04-21	2.65-21	1.47-21
650.0	3.55-22	2.28-21	1.28-21
700.0	1.13-22	1.94-21	1.08-21
800.0	2.96-23	1.69-21	8.33-22
900.0	3.56-24	1.48-21	6.57-22
1000.0	1.11-24	1.32-21	5.37-22
1250.0		1.19-21	3.38-22
1500.0		1.08-21	2.43-22
1750.0		9.81-22	1.93-22
2000.0		7.96-22	1.42-22
2250.0		6.74-22	1.19-22
2500.0		5.94-22	9.83-23
2700.0		5.07-22	7.90-23
3000.0		4.35-22	6.68-23
3250.0		3.00-22	5.73-23
3500.0		1.72-22	4.77-23
3750.0		4.84-23	4.04-23
4000.0		3.30-24	2.75-23
4250.0		1.93-24	1.09-23
4500.0			7.30-25
4500.0			7.30-25

Note: The low electron energy portion in these data was taken with a time-of-flight system and, thus, should be accurate down to about 1 eV.

Reference: These data were taken from D. J. Lynch, L. H. Toburen, and W. E. Wilson, J. Chem. Phys. 64, 2616 (1976).

Section I-2.C. SECONDARY ELECTRON SPECTRUM FOR PROTON IMPACT IONIZATION

Data Needed

I. Free Atoms: The noble gases are fairly well documented except for Kr, where no published data exist, and Xe, where more low energy data are needed (i.e., proton energies from 20 to 300 keV). No data exist for any other free atoms! Data are needed, over the entire proton energy range, for H, C, N, O, F, Cl, Br, I, Cd, Hg, and U.

II. Molecules (Monomers): Data are adequate for H_2, N_2, O_2, except that the range of O_2 data needs to be extended to higher proton energies from 300 keV to several MeV. Data for H_2O, C_2H_2, NH_3, and CH_4 are fragmentary and need to be complemented by lower proton energy data from 20 to about 200 keV. Molecules of importance for which no data exist are CO, CO_2, NO, F_2, Cl_2, Br_2, I_2, HF, HCl, and UF_6.

III. Molecules (Excimers): No secondary electron energy spectra exist for proton impact ionization of excimers! Data are needed for the various excimer combinations of noble gas atoms with each other as well as with halogen atoms. Data are needed on clusters as well.

IV. Excited States: No data exist for secondary electrons resulting from proton impact ionization of excited states of atoms or molecules. The data of particular importance that are needed are proton on metastable excited states of the various atoms and molecules of importance.

I-3. ENERGY SPECTRA OF SECONDARY ELECTRONS FROM HEAVY - ION IMPACT IONIZATION

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Section I-3.A. SECONDARY ELECTRON ENERGY SPECTRA FOR He^{+} AND He^{++} IMPACT IONIZATION OF AR

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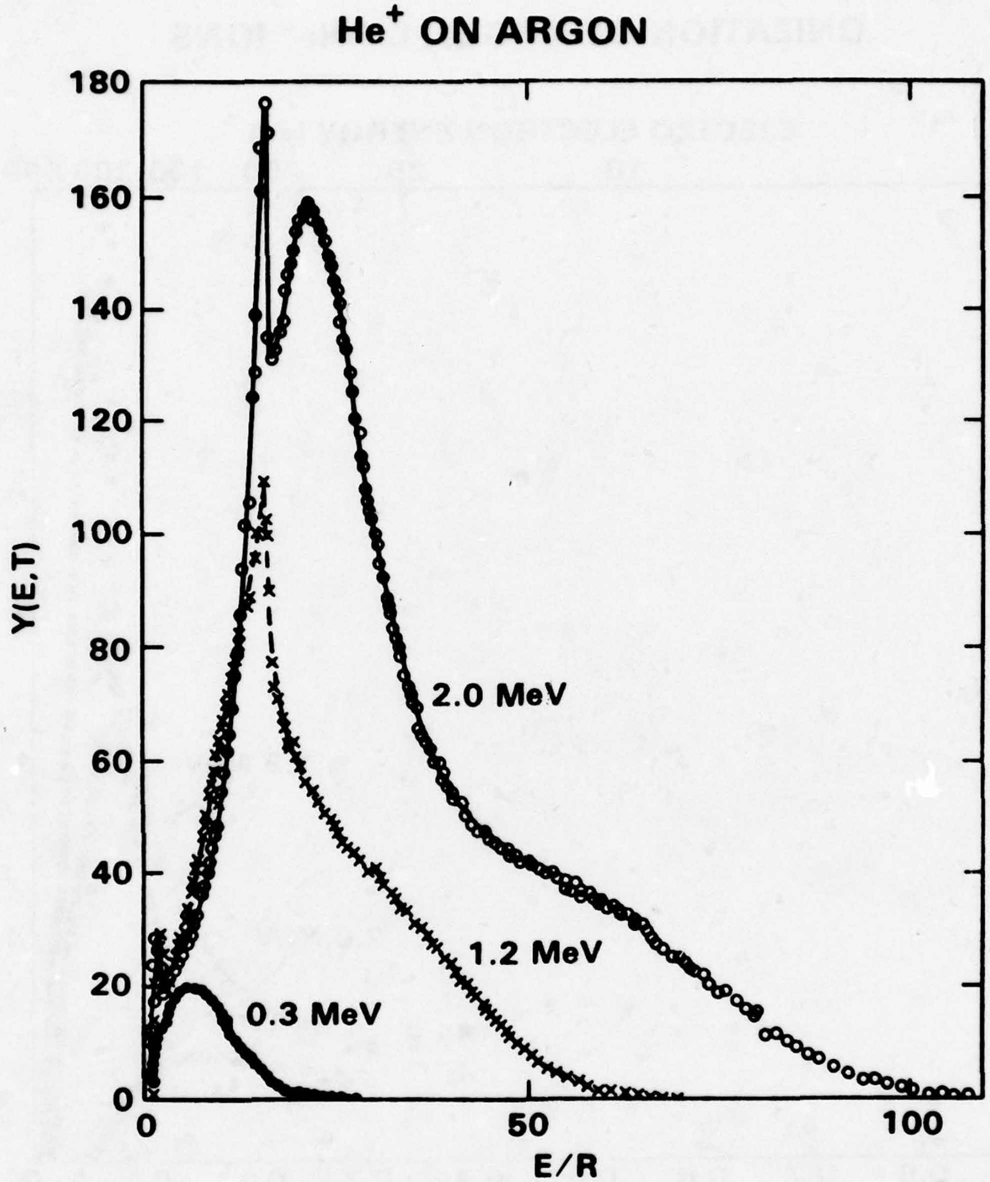
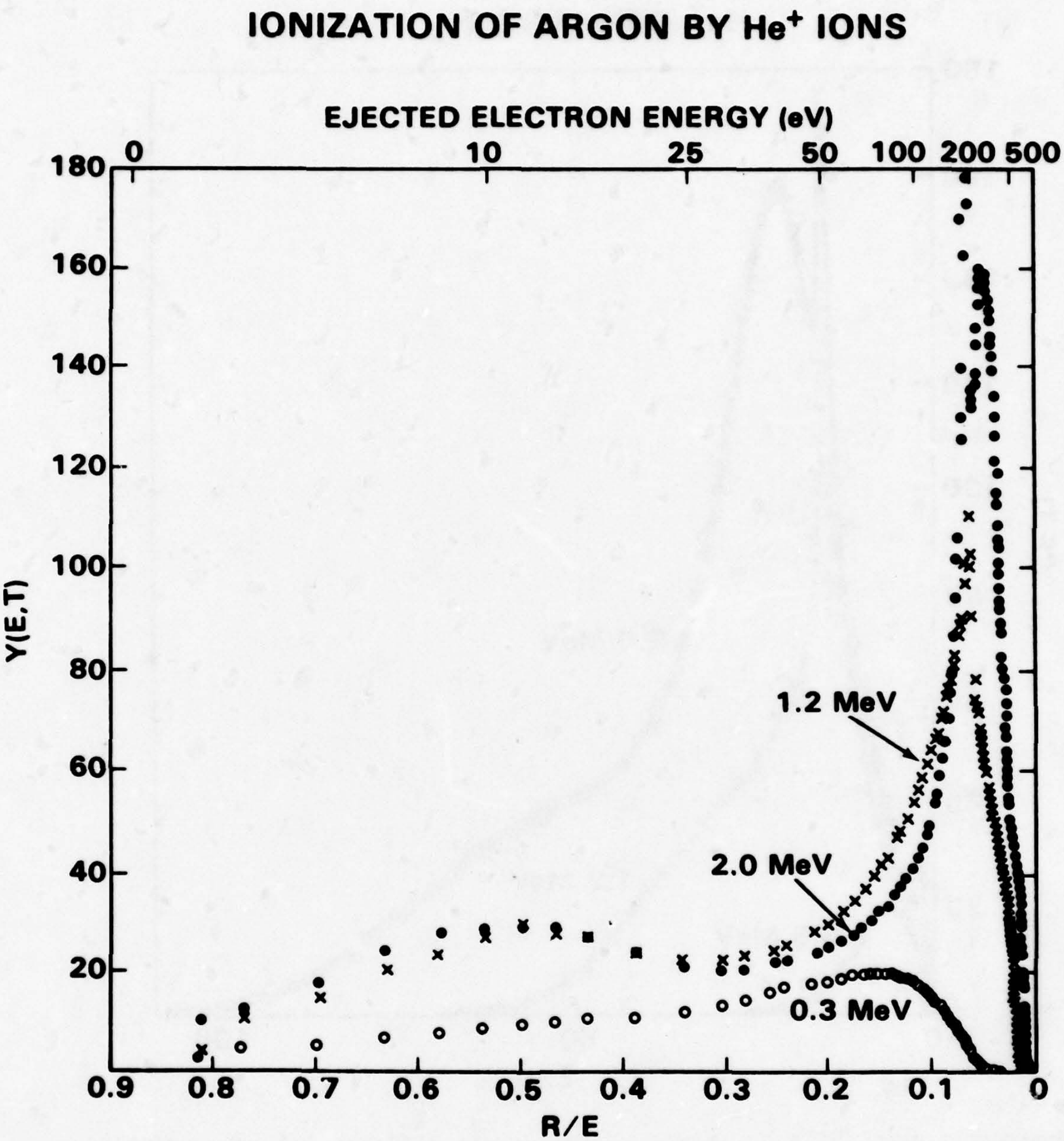
Tabular Data I-3.A-1. Single differential cross section (secondary electron spectra) for He^{+} + Ar collisions (units of cm^2/eV).

ENERGY (EV)	Proton Energy 0.3 MeV	0.8 MeV	1.2 MeV	1.6 MeV	2.0 MeV
0.0	1.26-18	1.26-18	1.26-18	1.26-18	1.26-18
1.0	1.45-17	3.15-17	4.79-18	1.65-17	8.74-18
2.0	2.28-17	2.95-17	1.26-17	2.33-17	9.36-18
4.0	2.25-17	2.64-17	1.47-17	1.93-17	1.12-17
6.0	2.39-17	2.39-17	1.71-17	1.72-17	1.25-17
8.0	2.28-17	1.98-17	1.68-17	1.53-17	1.21-17
10.0	2.16-17	1.75-17	1.62-17	1.35-17	1.08-17
15.0	1.81-17	1.15-17	1.19-17	8.55-18	6.92-18
25.0	1.18-17	6.12-18	5.23-18	3.70-18	2.91-18
50.0	6.65-18	3.68-18	2.64-18	1.86-18	1.35-18
75.0	3.83-18	2.69-18	2.00-18	1.33-18	9.22-19
100.0	2.15-18	1.97-18	1.61-18	1.09-18	7.21-19
150.0	5.74-19	1.02-18	1.13-18	9.57-19	6.46-19
200.0	1.45-19	6.49-19	8.72-19	1.02-18	8.79-19
250.0	2.26-20	2.85-19	3.54-19	4.80-19	5.03-19
300.0	5.04-21	1.59-19	2.09-19	2.80-19	3.71-19
350.0	4.58-22	8.72-20	1.33-19	1.64-19	2.35-19
350.0	4.58-22	8.72-20	1.33-19	1.64-19	2.35-19
400.0		4.33-20	8.94-20	1.03-19	1.38-19
450.0		1.93-20	6.23-20	7.02-20	8.40-20
500.0		7.38-21	4.15-20	5.11-20	5.52-20
550.0		2.70-21	2.63-20	3.86-20	3.89-20
600.0		7.89-22	1.50-20	2.96-20	2.91-20
650.0		2.42-22	8.68-21	2.26-20	2.32-20
700.0		3.12-23	4.53-21	1.69-20	1.91-20
750.0			2.31-21	1.21-20	1.55-20
800.0			1.05-21	8.16-21	1.27-20
850.0			4.72-22	5.16-21	1.03-20
900.0			1.96-22	3.11-21	8.11-21
950.0			7.42-23	1.80-21	6.26-21
1000.0			3.27-23	1.08-21	4.88-21
1100.0			1.74-23	2.80-22	2.43-21
1200.0			4.03-24	8.09-23	1.05-21
1300.0				1.22-23	4.11-22
1400.0					1.51-22
1500.0					4.00-23
1750.0					1.46-24

Reference: These data were taken from L. H. Toburen and W. Wilson, XICPEAC, Abstracts of Papers, p. 1006 and Phys. Rev. A., to be published (1979).



Graphical Data I-3.A-2. Ratio of the single differential cross section to the Rutherford cross section; see the General Comments at the beginning of this chapter for more details. These data were taken from L. H. Toburen and W. E. Wilson, XICPEAC, Abstracts of Papers, p. 1006 and Phys. Rev. A, to be published (1979).



Graphical Data I-3.A-3. Ratio of the single differential cross section to the Rutherford cross section; see the General Comments at the beginning of this chapter for more details. These data were taken from L. H. Toburen and W. E. Wilson, XICPEAC, Abstracts of Papers, p. 1006 and Phys. Rev. A, to be published (1979).

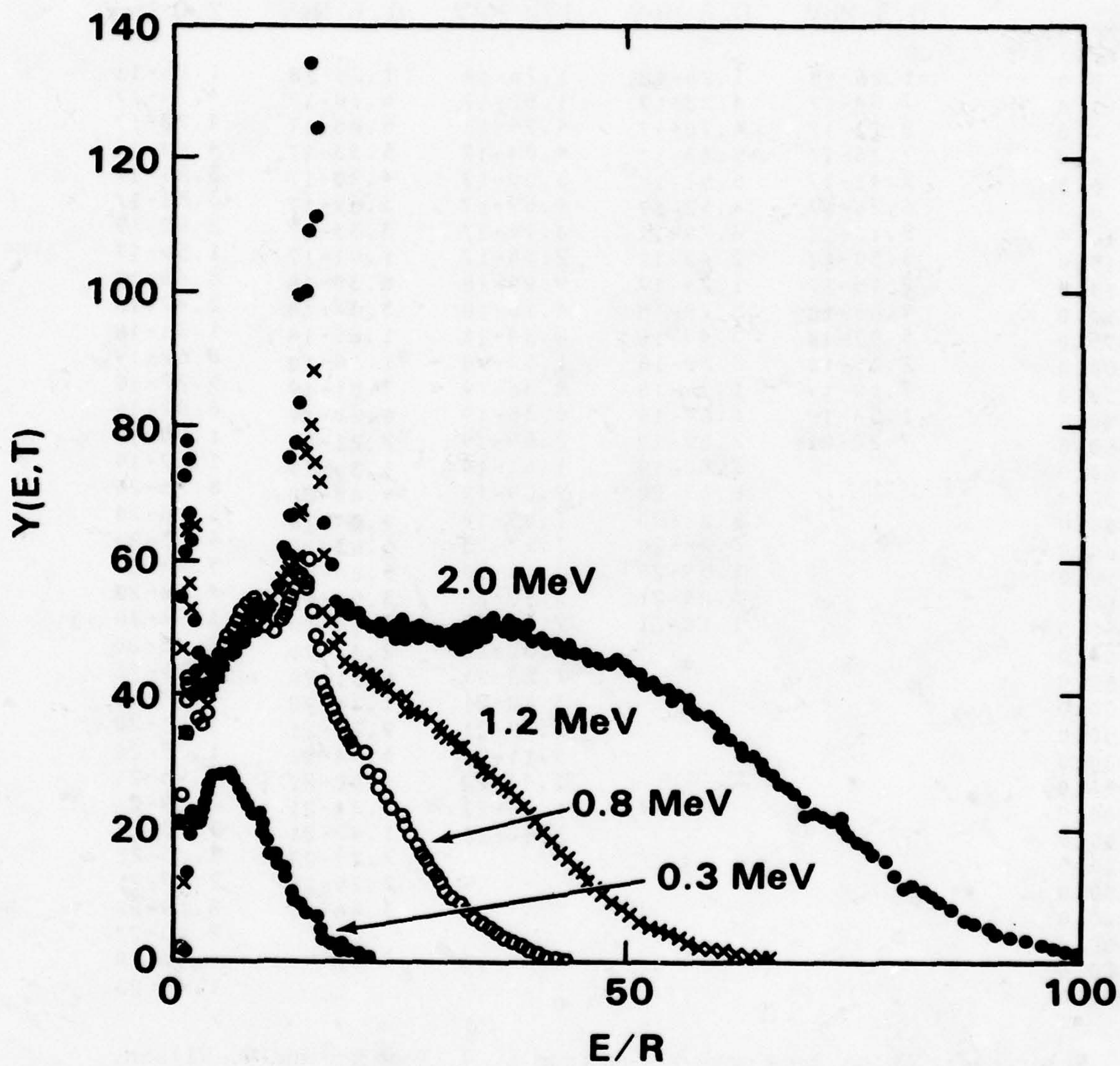
Tabular Data I-3.A-4. Single differential cross section (secondary electron spectra) for He^{++} + Ar collisions (units of cm^2/eV).

Proton Energy

ENERGY (EV)	0.3 MeV	0.8 MeV	1.2 MeV	1.6 MeV	2.0 MeV
0.0	1.26-18	1.26-18	1.26-18	1.26-18	1.26-18
1.0	7.04-17	4.33-17	1.52-17	6.18-17	4.74-17
2.0	9.17-17	4.70-17	4.25-17	5.88-17	4.72-17
4.0	7.76-17	5.43-17	4.84-17	5.33-17	4.44-17
6.0	7.41-17	5.51-17	5.09-17	4.70-17	3.89-17
8.0	6.20-17	4.52-17	4.59-17	3.89-17	3.31-17
10.0	5.16-17	3.79-17	3.96-17	3.33-17	2.82-17
15.0	3.59-17	2.42-17	2.30-17	1.91-17	1.59-17
25.0	2.15-17	1.24-17	9.90-18	8.30-18	6.40-18
50.0	9.88-18	5.78-18	4.15-18	3.37-18	2.47-18
75.0	5.07-18	3.49-18	2.34-18	1.85-18	1.31-18
100.0	2.65-18	2.29-18	1.50-18	1.16-18	8.62-19
150.0	7.10-19	1.09-18	8.36-19	7.01-19	5.27-19
200.0	1.54-19	6.64-19	6.36-19	6.80-19	6.02-19
250.0	7.20-21	2.89-19	2.50-19	2.21-19	1.70-19
300.0		1.60-19	1.61-19	1.36-19	1.17-19
350.0		8.07-20	1.09-19	9.09-20	8.76-20
350.0		8.07-20	1.09-19	9.09-20	8.76-20
400.0		3.70-20	7.57-20	6.63-20	6.63-20
450.0		1.59-20	5.15-20	5.00-20	5.43-20
500.0		6.00-21	3.50-20	3.92-20	4.48-20
550.0		1.16-21	2.20-20	3.08-20	3.54-20
600.0			1.32-20	2.32-20	2.90-20
650.0			7.22-21	1.81-20	2.39-20
700.0			3.80-21	1.36-20	1.97-20
750.0			1.78-21	9.29-21	1.61-20
800.0			8.11-22	6.44-21	1.30-20
850.0			3.44-22	4.08-21	9.96-21
900.0			1.13-22	2.41-21	7.69-21
950.0			3.89-23	1.42-21	5.73-21
1000.0				7.73-22	4.23-21
1100.0				7.79-23	2.07-21
1200.0				3.46-23	8.10-22
1300.0					2.40-22
1400.0					6.40-23
1500.0					1.45-23

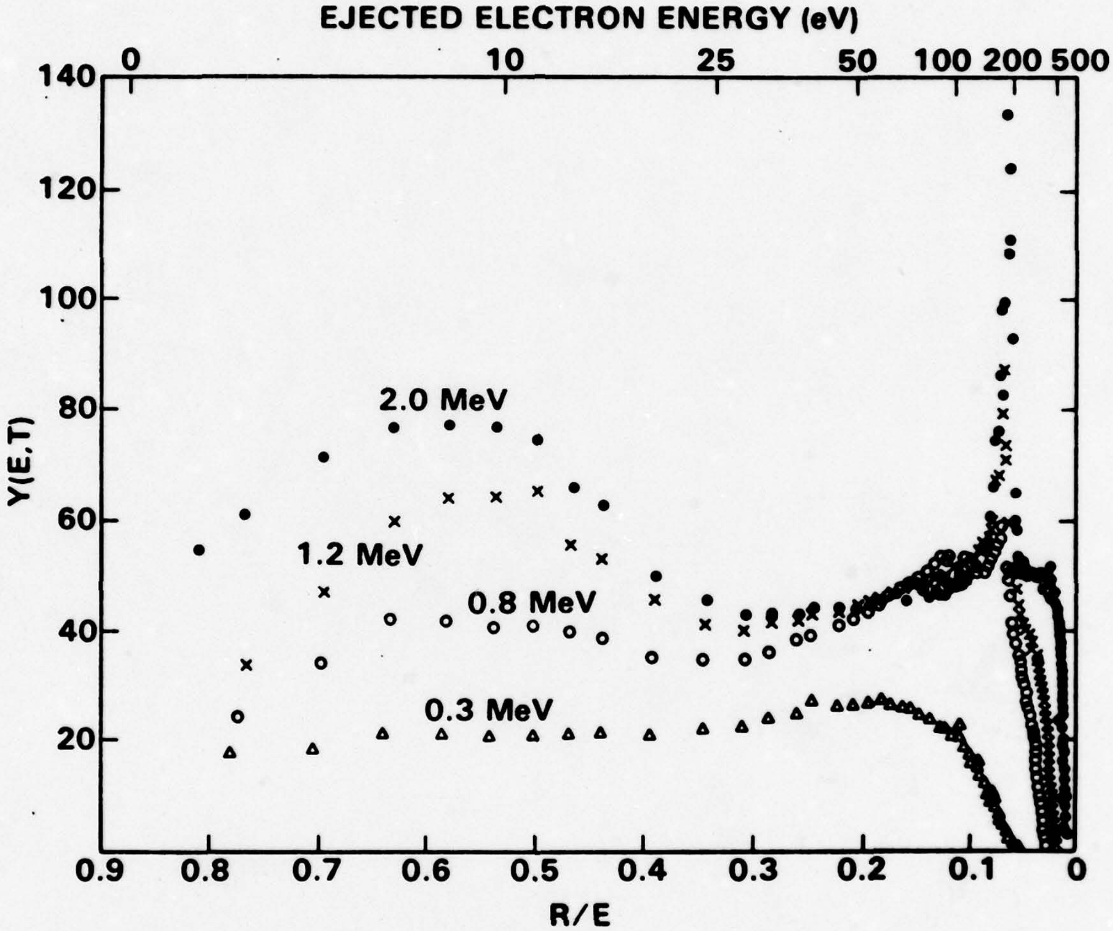
Reference: These data were taken from L. H. Toburen and W. Wilson, XICPEAC, Abstracts of Papers, p. 1006 and Phys. Rev. A., to be published (1979).

ALPHA PARTICLE IONIZATION OF ARGON



Graphical Data I-3.A-5. Ratio of the single differential cross section to the Rutherford cross section; see the General Comments at the beginning of this chapter for more details. These data were taken from L. H. Toburen and W. E. Wilson, <u>XICPEAC</u>, Abstracts of Papers, p. 1006 and Phys. Rev. A., to be published (1979).

ALPHA PARTICLE IONIZATION OF ARGON



Graphical Data I-3.A-6. Ratio of the single differential cross section to the Rutherford cross section; see the General Comments at the beginning of this chapter for more details. These data were taken from L. H. Toburen and W. E. Wilson, XICPEAC, Abstracts of Papers, P. 1006 and Phys. Rev. A., to be published (1979).

Section I-3.B. SECONDARY ELECTRON ENERGY SPECTRA FOR Ne^{+} + Ne AND Ar^{+} + Ar COLLISIONS

CONTENTS

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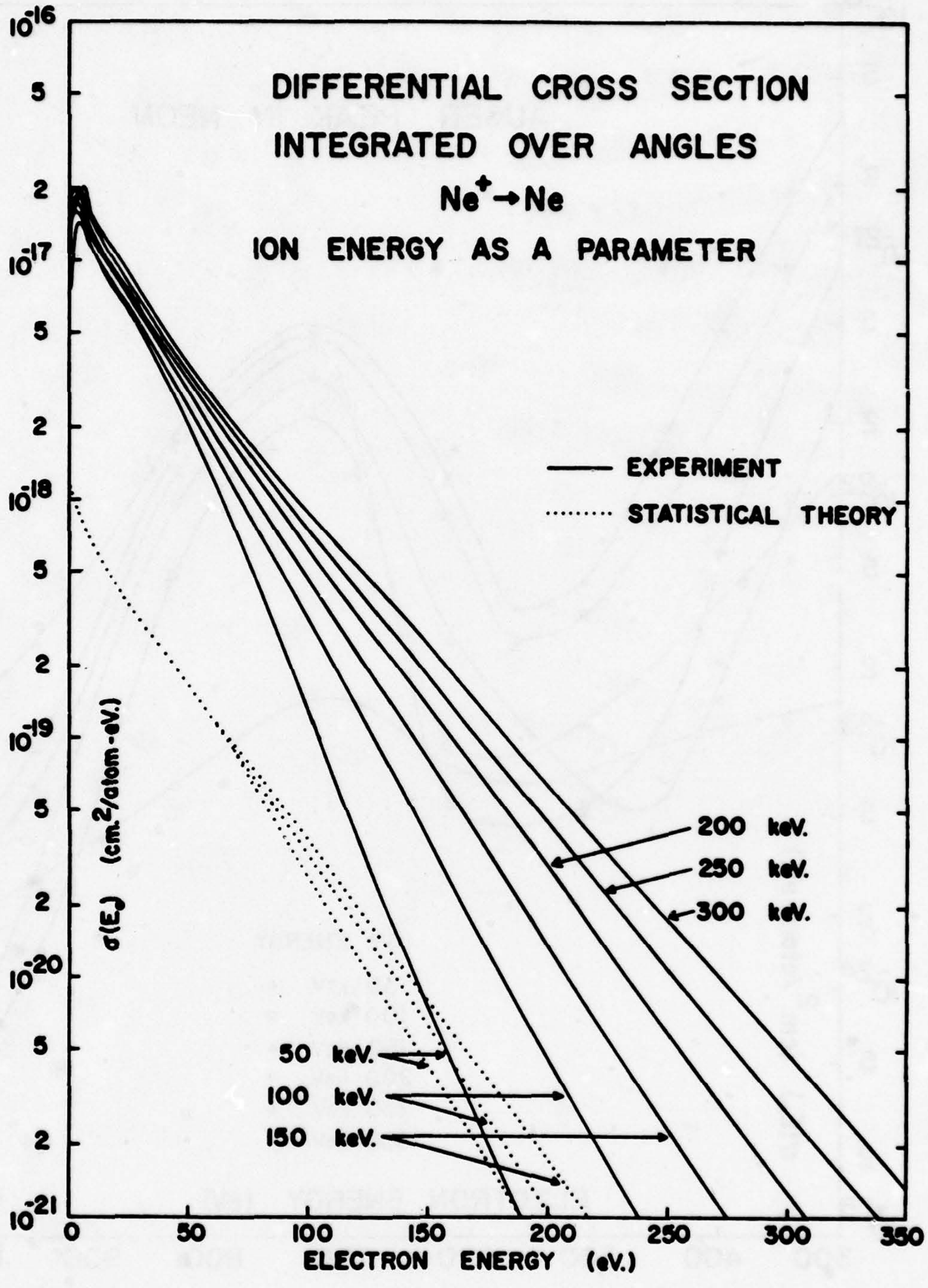
Tabular Data I-3.B-1. Single differential cross section (secondary electron spectra) for Ne^+ + Ne collisions (units of cm^2/eV).

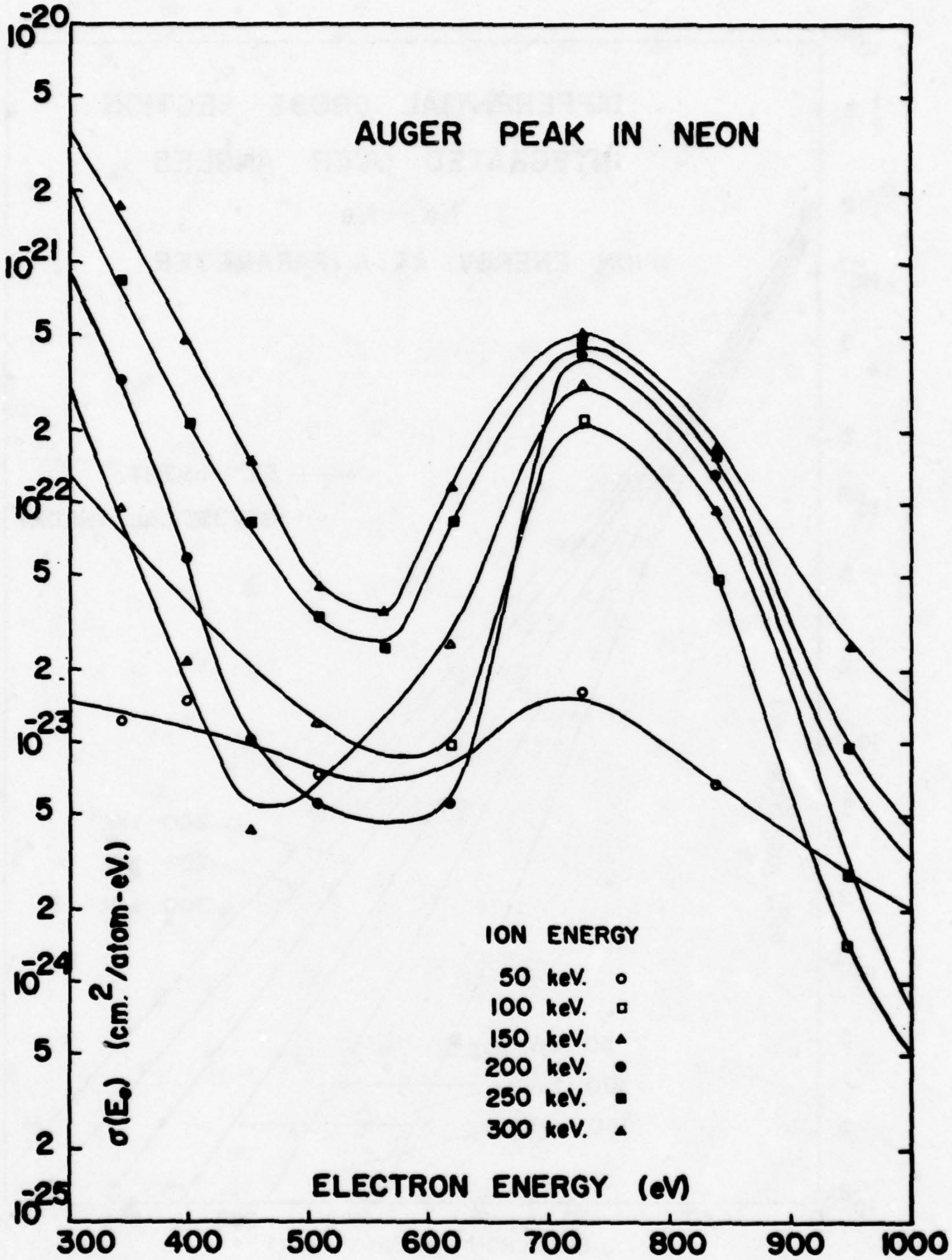
Proton Energy

ELECTRON ENERGY (EV)	50 KEV	100 KEV	150 KEV	200 KEV	250 KEV	300 KEV
0.0	6.100E-18	6.758E-18	7.557E-18	8.188E-18	9.294E-18	1.005E-17
1.49	8.831E-18	9.973E-18	1.092E-17	1.154E-17	1.234E-17	1.287E-17
3.41	1.458E-17	1.636E-17	1.799E-17	1.891E-17	1.905E-17	1.875E-17
5.34	1.420E-17	1.545E-17	1.693E-17	1.808E-17	1.915E-17	1.819E-17
7.26	1.272E-17	1.370E-17	1.540E-17	1.643E-17	1.775E-17	1.746E-17
9.18	1.139E-17	1.223E-17	1.369E-17	1.467E-17	1.578E-17	1.620E-17
11.11	1.007E-17	1.075E-17	1.182E-17	1.279E-17	1.427E-17	1.463E-17
13.03	9.302E-18	9.744E-18	1.064E-17	1.158E-17	1.244E-17	1.316E-17
17.15	8.265E-18	8.720E-18	9.165E-18	9.720E-18	1.050E-17	1.109E-17
21.27	7.043E-18	7.501E-18	7.951E-18	8.463E-13	9.086E-18	9.730E-18
25.40	5.980E-18	6.461E-18	6.878E-18	7.263E-18	7.904E-18	8.414E-18
29.52	4.974E-16	5.407E-18	5.744E-18	6.066E-18	6.580E-18	6.851E-18
33.64	4.241E-18	4.764E-18	4.981E-18	5.321E-18	5.702E-18	6.095E-18
37.76	3.531E-18	4.093E-18	4.399E-18	4.711E-18	4.985E-18	5.478E-18
47.38	2.209E-18	2.808E-18	3.144E-18	3.424E-18	3.706E-18	4.024E-16
57.00	1.340E-18	1.929E-18	2.257E-18	2.477E-18	2.707E-18	2.971E-18
66.62	8.114E-19	1.306E-18	1.619E-18	1.826E-18	2.026E-18	2.199E-18
76.23	4.815E-19	8.871E-19	1.157E-18	1.352E-18	1.527E-18	1.687E-18
85.85	2.866E-19	6.002E-19	8.311E-19	1.008E-18	1.154E-18	1.291E-18
95.47	1.692E-19	4.053E-19	5.927E-19	7.459E-19	8.769E-19	1.000E-18
109.21	7.958E-20	2.328E-19	3.697E-19	4.890E-19	5.973E-19	6.943E-19
122.95	3,686E-20	1.329E-19	2.296E-19	3.213E-19	4.038E-19	4.864E-19
136.69	1.734E-20	7.428E-20	1.423E-19	2.095E-19	2.754E-19	3.408E-19
150.43	8.090E-21	4.182E-20	8.676E-20	1.370E-19	1.861E-19	2.370E-19
164.17	3.831E-21	2.312E-20	5.417E-20	8.959E-20	1.266E-19	1.655E-19
177.91	1.878E-21	1.306E-20	3.367E-20	5.855E-20	8.562E-20	1.158E-19
191.65	8.906E-22	7.146E-21	2.032E-20	3.799E-20	5.847E-20	8.099E-20
205.39	4.740E-22	4.046E-21	1.331E-20	2.479E-20	3.979E-20	5.701E-20
219.13	2.469E-22	2.289E-21	7.603E-21	1.635E-20	2.696E-20	3.965E-20
232.87	1.649E-22	1.276E-21	4.663E-21	1.053E-20	1.839E-20	2.774E-20
246.61	6.690E-23	7.521E-22	2.963E-21	6.721E-21	1.227E-20	1.984E-20
260.35	5.581E-23	4.195E-22	1.778E-21	4.309E-21	9.325E-21	1.381E-20
274.09	2.024E-23	2.579E-22	1.082E-21	2.826E-21	5.786E-21	9.696E-21
287.83	2.642E-23	1.486E-22	6.717E-22	1.835E-21	3.851E-21	6.841E-21
342.79	2.420E-23	1.511E-23	1.016E-22	3.436E-22	8.576E-22	1.722E-21
397.75	1.863E-23	3.342E-25	2.676E-23	7.177E-23	2.168E-22	4.740E-22
452.71	1.356E-24	1.443E-23	1.524E-23	2.194E-23	8.178E-23	1.515E-22
507.67	1.800E-23	2.849E-24	1.579E-23	1.044E-23	3.323E-23	4.609E-23
562.63	2.446E-24	3.936E-24	3.539E-24	6.459E-24	2.524E-23	3.678E-23
617.59	4.887E-24	9.396E-24	2.553E-23	6.021E-23	6.606E-23	1.223E-22
727.51	2.207E-23	2.222E-22	3.140E-22	4.225E-22	4.477E-22	5.233E-22
837.43	1.030E-23	4.743E-23	9.221E-23	1.383E-22	1.598E-22	1.645E-22
947.35	6.062E-24	3.797E-24	3.559E-24	4.982E-24	1.035E-23	2.500E-23
1057.27	3.073E-24	2.818E-25	3.387E-24	1.320E-24	5.176E-24	1.340E-23

Reference: These data were taken from J. R. Cacak and T. Jorgenson, Jr., Phys. Rev. A 2, 1322 (1970).



Graphical Data I-3.B-2. Single differential cross section for Ne^{+} + Ne. These data were taken from J. R. Cacak, thesis (University of Nebraska, 1969).

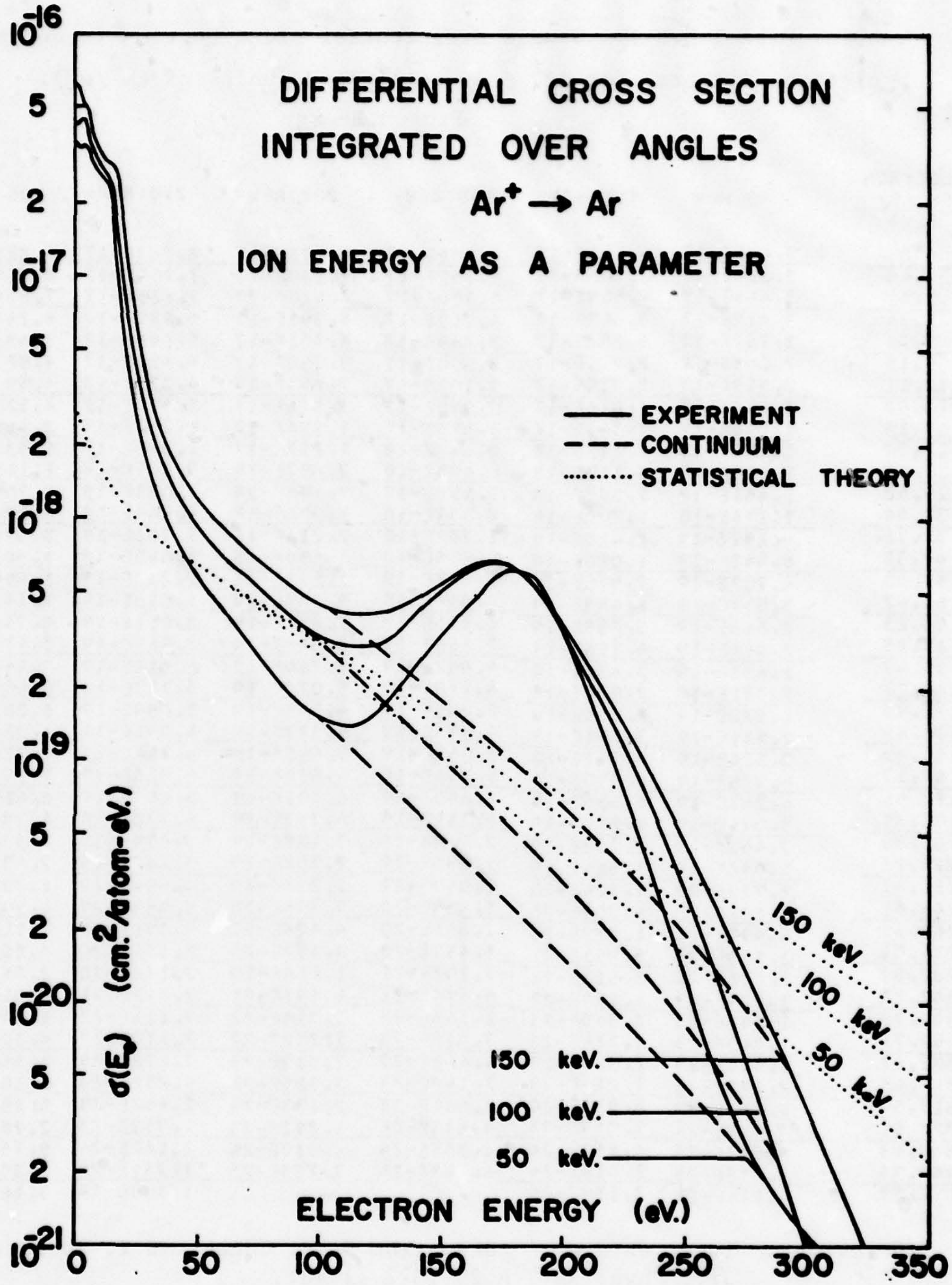


Graphical Data I-3.B-3. Single differential cross section for Ne^+ + Ne. These data were taken from J. R. Cacak, thesis (University of Nebraska, 1969).

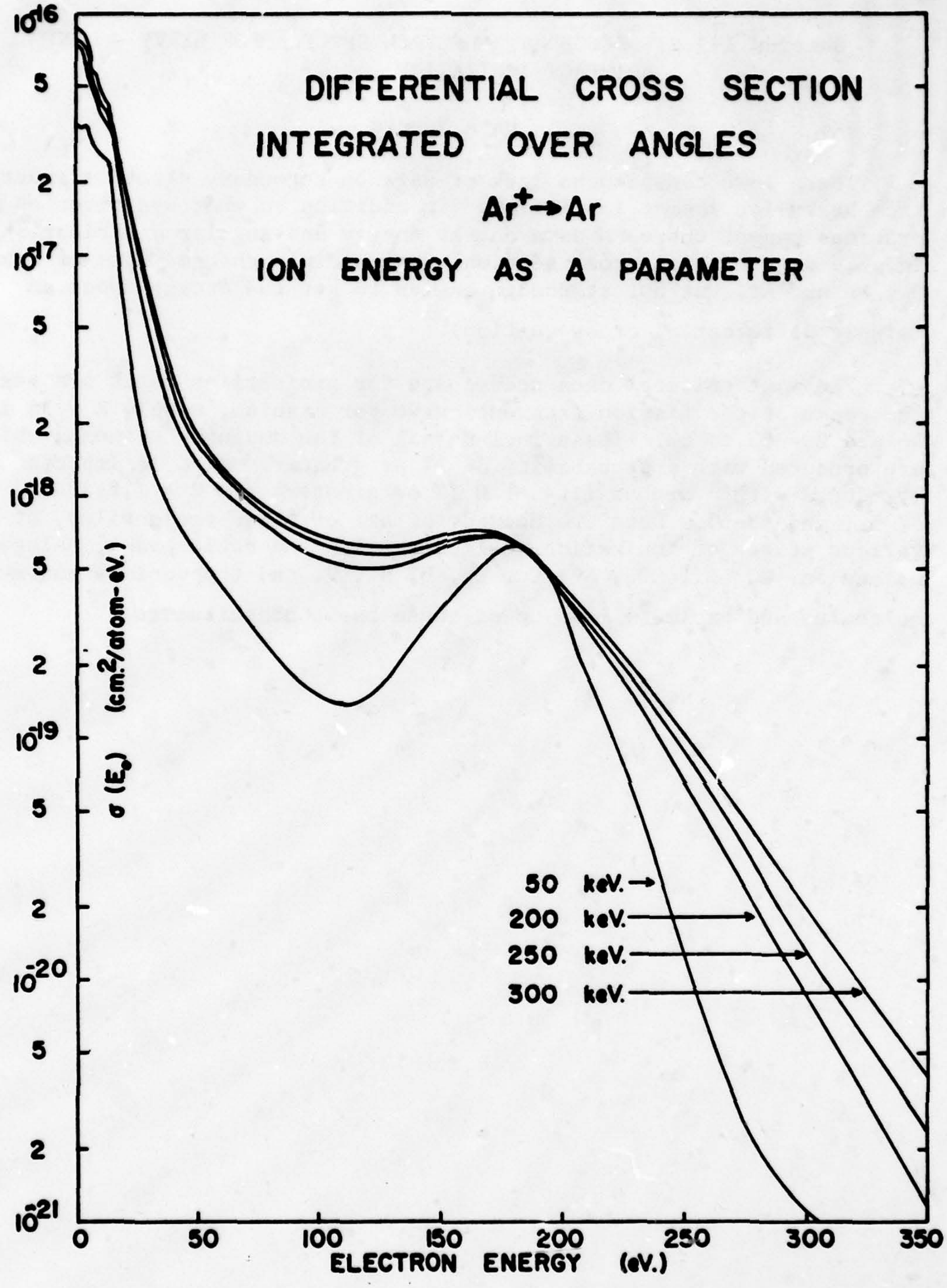
Tabular Data I-3.B-4. Single differential cross section (secondary electron spectra) for $Ar^{+} + Ar$ collisions (units of cm^2/eV).

	Proton Energy					
ELECTRON ENERGY (EV)	50 KEV	100 KEV	150 KEV	200 KEV	250 KEV	300 KEV
0.0	3.435E-17	4.166E-17	6.506E-17	8.183E-17	8.063E-17	9.023E-17
1.49	3.320E-17	4.209E-17	5.792E-17	7.180E-17	7.769E-17	8.350E-17
3.41	3.443E-17	4.509E-17	5.300E-17	6.410E-17	7.625E-17	7.878E-17
5.34	3.017E-17	3.649E-17	4.250E-17	4.991E-17	5.888E-17	6.248E-17
7.26	2.767E-17	3.256E-17	3.849E-17	4.401E-17	5.180E-17	5.637E-17
9.18	2.665E-17	2.971E-17	3.390E-17	3.860E-17	4.428E-17	4.927E-17
11.11	2.519E-17	2.710E-17	3.102E-17	3.643E-17	4.225E-17	4.597E-17
13.03	2.444E-17	2.646E-17	2.995E-17	3.376E-17	3.780E-17	4.123E-17
17.15	1.099E-17	1.347E-17	1.619E-17	1.954E-17	2.263E-17	2.461E-17
21.27	5.193E-18	7.512E-18	9.643E-18	1.157E-17	1.349E-17	1.534E-17
25.40	2.239E-18	4.122E-18	6.405E-18	7.697E-18	9.461E-18	1.143E-17
29.52	1.461E-18	2.297E-18	3.458E-18	5.186E-18	7.483E-18	8.700E-18
33.64	1.104E-18	1.740E-18	2.317E-18	3.006E-18	4.168E-18	5.574E-18
37.76	9.182E-19	1.415E-18	1.782E-18	2.214E-18	2.762E-18	3.379E-18
47.38	6.442E-19	1.020E-18	1.235E-18	1.435E-18	1.665E-18	1.907E-18
57.00	4.702E-19	7.975E-19	9.822E-19	1.132E-18	1.263E-18	1.494E-18
66.62	3.507E-19	6.488E-19	8.038E-19	9.383E-19	1.045E-18	1.141E-18
76.23	2.665E-19	5.248E-19	6.715E-19	7.831E-19	8.851E-19	9.744E-19
85.85	2.046E-19	4.218E-19	5.664E-19	6.646E-19	7.567E-19	8.432E-19
95.47	1.632E-19	3.491E-19	4.862E-19	5.784E-19	6.618E-19	7.448E-19
109.21	1.381E-19	2.912E-19	4.118E-19	5.076E-19	5.783E-19	6.499E-19
122.95	1.570E-19	2.929E-19	4.004E-19	4.948E-19	5.699E-19	6.287E-19
136.69	2.451E-19	3.561E-19	4.533E-19	5.327E-19	5.933E-19	6.367E-19
150.43	3.326E-19	4.717E-19	5.456E-19	5.995E-19	6.364E-19	6.726E-19
164.17	4.978E-19	6.010E-19	6.354E-19	6.695E-19	6.928E-19	7.198E-19
177.91	6.267E-19	6.636E-19	6.650E-19	6.701E-19	6.669E-19	6.619E-19
191.65	5.071E-19	4.850E-19	4.731E-19	4.712E-19	4.738E-19	4.786E-19
205.39	2.445E-19	2.733E-19	2.968E-19	3.185E-19	3.374E-19	3.534E-19
219.13	1.098E-19	1.524E-19	1.885E-19	2.202E-19	2.467E-19	2.693E-19
232.87	4.712E-20	7.414E-20	1.030E-19	1.317E-19	1.571E-19	1.787E-19
246.61	1.691E-20	3.367E-20	5.318E-20	7.395E-20	9.356E-20	1.106E-19
260.35	5.490E-21	1.512E-20	2.861E-20	4.409E-20	5.791E-20	7.118E-20
274.09	1.560E-21	5.951E-21	1.457E-20	2.492E-20	3.555E-20	4.559E-20
287.83	5.076E-22	2.513E-21	7.202E-21	1.416E-20	2.178E-20	2.917E-20
342.79	1.679E-23	1.129E-22	6.894E-22	1.691E-21	3.312E-21	5.318E-21
397.75	1.243E-23	2.580E-23	1.363E-22	3.318E-22	7.114E-22	1.244E-21
452.71	1.740E-23	2.774E-23	7.418E-23	1.202E-22	2.110E-22	4.207E-22
507.67	2.434E-23	2.313E-23	4.443E-23	7.089E-23	7.622E-23	1.556E-22
562.63	2.175E-23	1.232E-23	2.169E-23	3.325E-23	4.866E-23	6.109E-23
617.59	2.071E-23	6.938E-24	2.061E-23	2.178E-23	2.492E-23	5.256E-23
727.51	7.687E-24	1.059E-23	9.035E-24	1.292E-23	1.752E-23	2.284E-23
837.43	4.237E-25	6.163E-24	6.305E-24	4.317E-24	3.160E-24	5.759E-24
947.35	2.178E-25	2.618E-24	6.143E-24	7.725E-25	1.771E-24	5.809E-24
1057.27	6.516E-26	3.139E-24			1.365E-24	3.165E-24

Reference: These data were taken from J. R. Cacak and T. Jorgenson, Jr., Phys. Rev. A 2, 1322 (1970).



Graphical Data I-3.B-5. Single differential cross section for Ar^+ + Ar. These data were taken from J. E. Cacak, thesis (University of Nebraska, 1969).



Graphical Data I-3.B-6. Single differential cross section for Ar^+ + Ar. These data were taken from J. R. Cacak, thesis (University of Nebrasks, 1969).

Section I-3.C. SECONDARY ELECTRON SPECTRA FOR HEAVY - ION IMPACT IONIZATION

Data Needed

There is a conspicuous lack of data on secondary electron spectra from heavy-ion impact ionization. In addition to what was given on the previous pages, there are data on the energy and angular distribution (double differential cross section) for multiple charged ions of oxygen on O_2, Ne and Ar, but not at enough angles to get the energy spectrum (single differential cross section).

The most critical data needed are for projectiles which are near the peaks of the fission fragment curve for uranium, namely Z = 38 to 46 and Z = 53 to 62. These include all of the daughter elements which are produced with a probability of 1% or greater. Also of importance (produced with a probability of 0.1% or greater) are Z = 1,2,33-37, 47-52, and 63-65. Data are needed for all of these projectiles, at various stages of ionization, colliding with the noble gases, halogen molecules, CO, N_2, CO_2, NO, Cd, Hg, H, H_2, U, and the various monomer molecules and excimers made up of these basic constituents.

I-4. ENERGY AND ANGULAR DISTRIBUTIONS OF SECONDARY ELECTRONS

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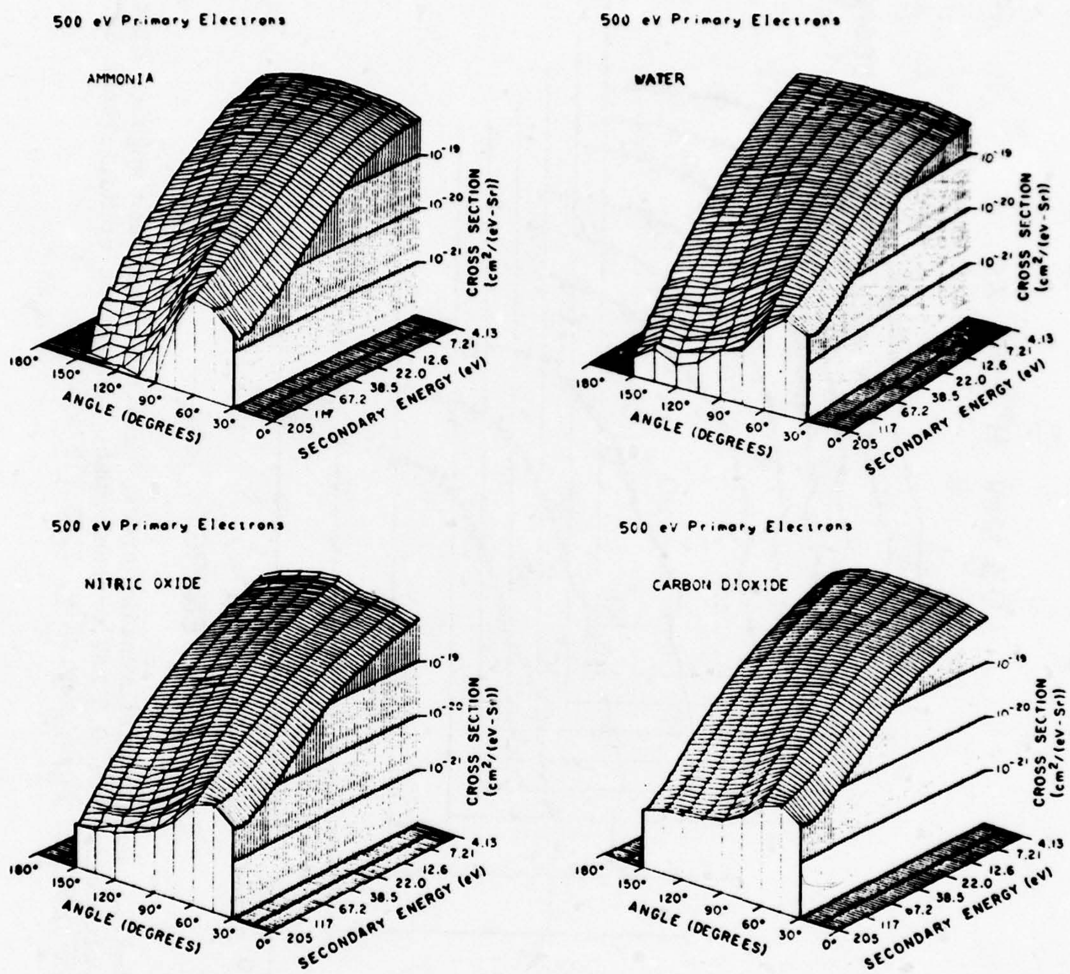
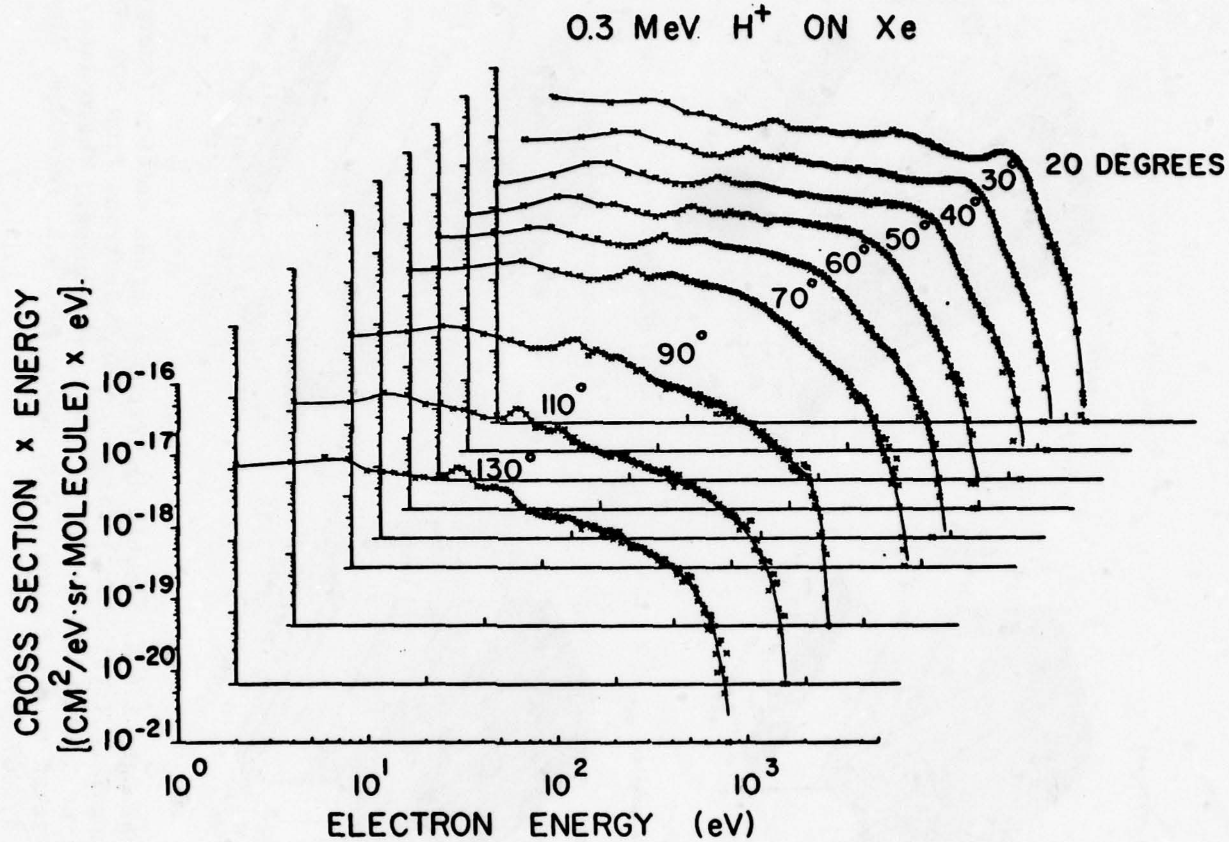
General Comments

Data on the angular distribution of secondary electrons are not of great importance in situations where pressure is greater than $\sim$ 1 Torr. This is because multiple collisions will rapidly change the initial angular distribution to one that is fairly isotropic.

It is possbile, however, that unforeseen situations might arise for which the angular distribution is of importance. Therefore, representative sampling of the type of data available has been included.



Graphical Data I-4.1. Double differential cross section (energy and angular distribution) for secondary electrons from 500 eV electron impact ionization of several molecules. These data were taken from C.B. Opal, E.C. Beaty, and W.K. Peterson, Atomic Data 4, 209 (1972).



Graphical Data I-4.2. Double differential cross section (energy and angular distribution) for secondary electrons from 0.3 MeV proton impact ionization of Xe. These data were taken from L.H. Toburen, Phys. Rev. A 9, 2505 (1974).

J. NUCLEAR DATA

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J-1. FISSION-PRODUCT YIELDS FROM NEUTRON-INDUCED FISSION

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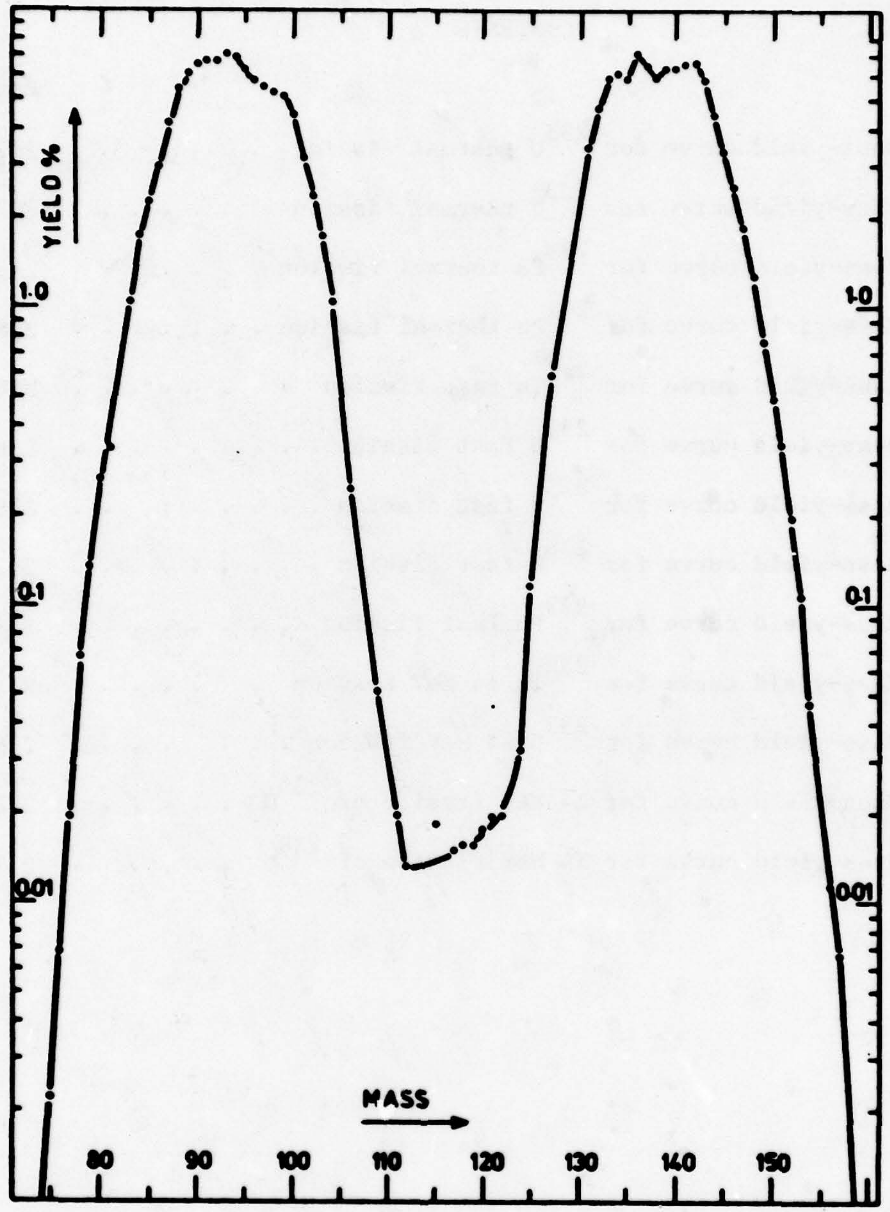
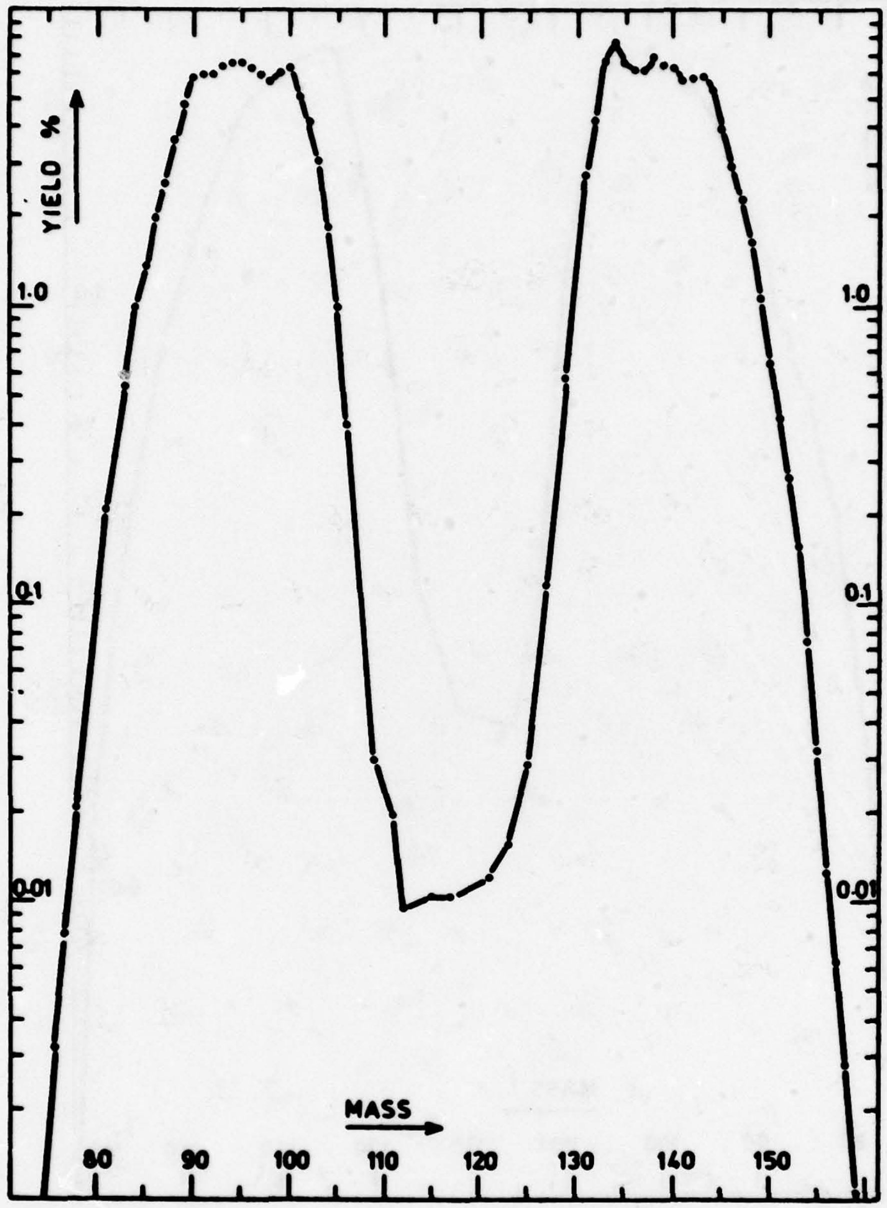
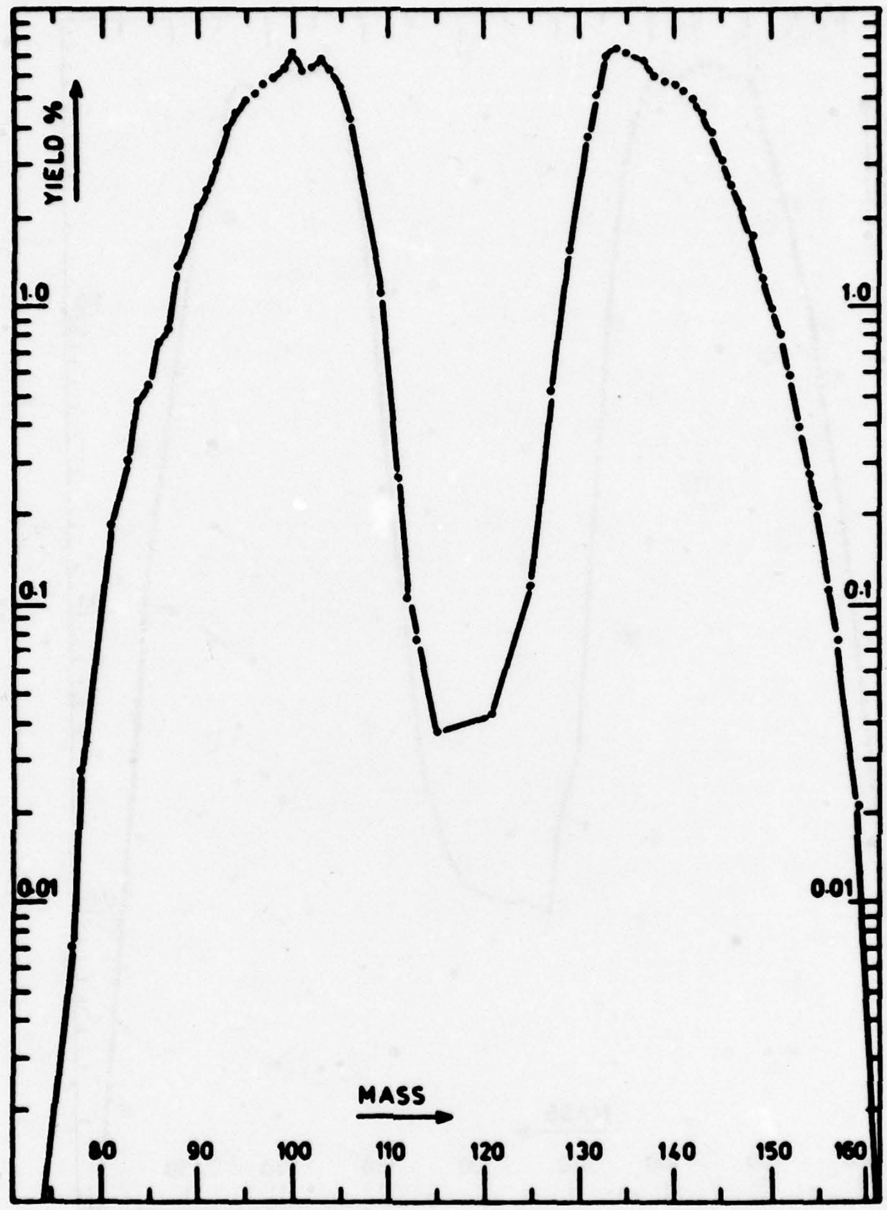


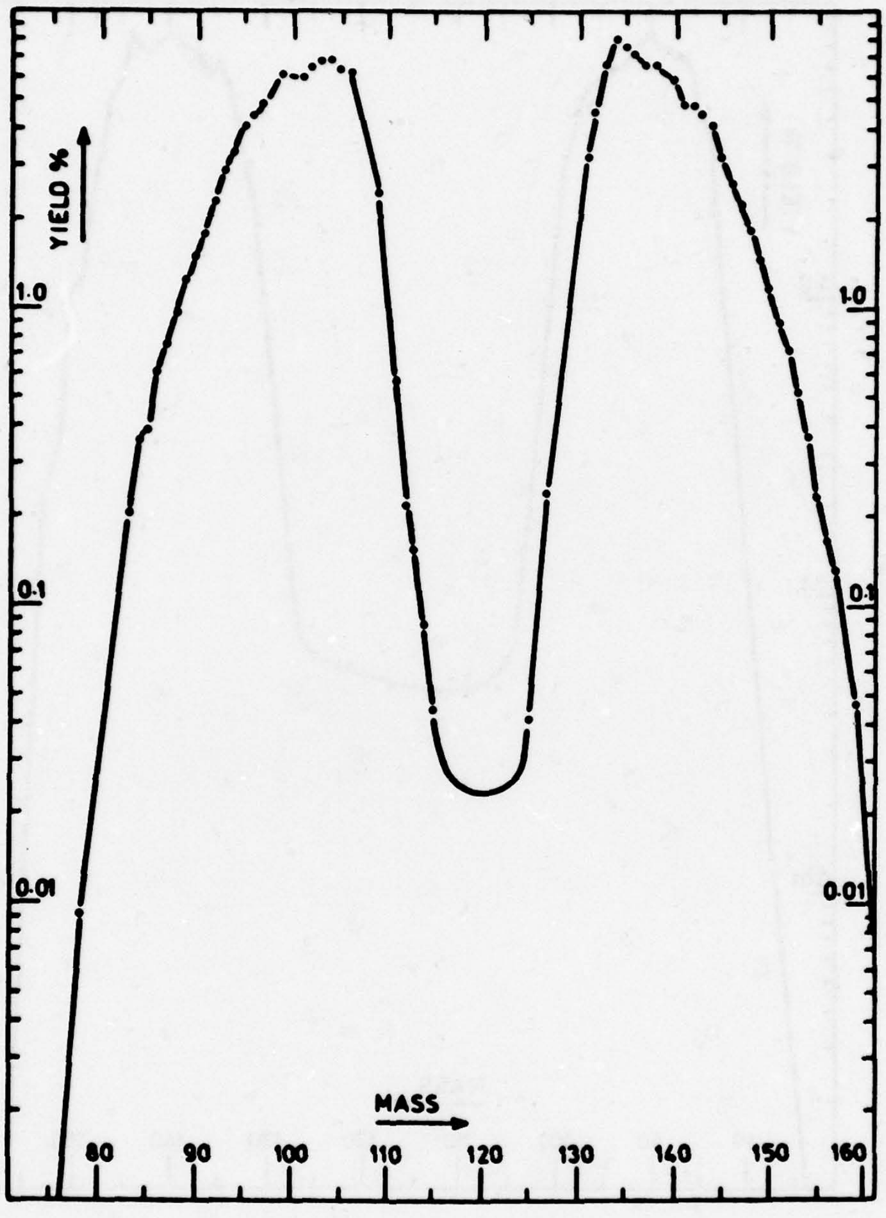
Graphical Data J-1.1. Mass-yield curve for ^{233}U thermal fission. These data were taken from E.A.C. Crouch, "Fission-Product Yields from Neutron-Induced Fission", Atomic Data and Nuclear Data Tables 19, 417-532 (1977).



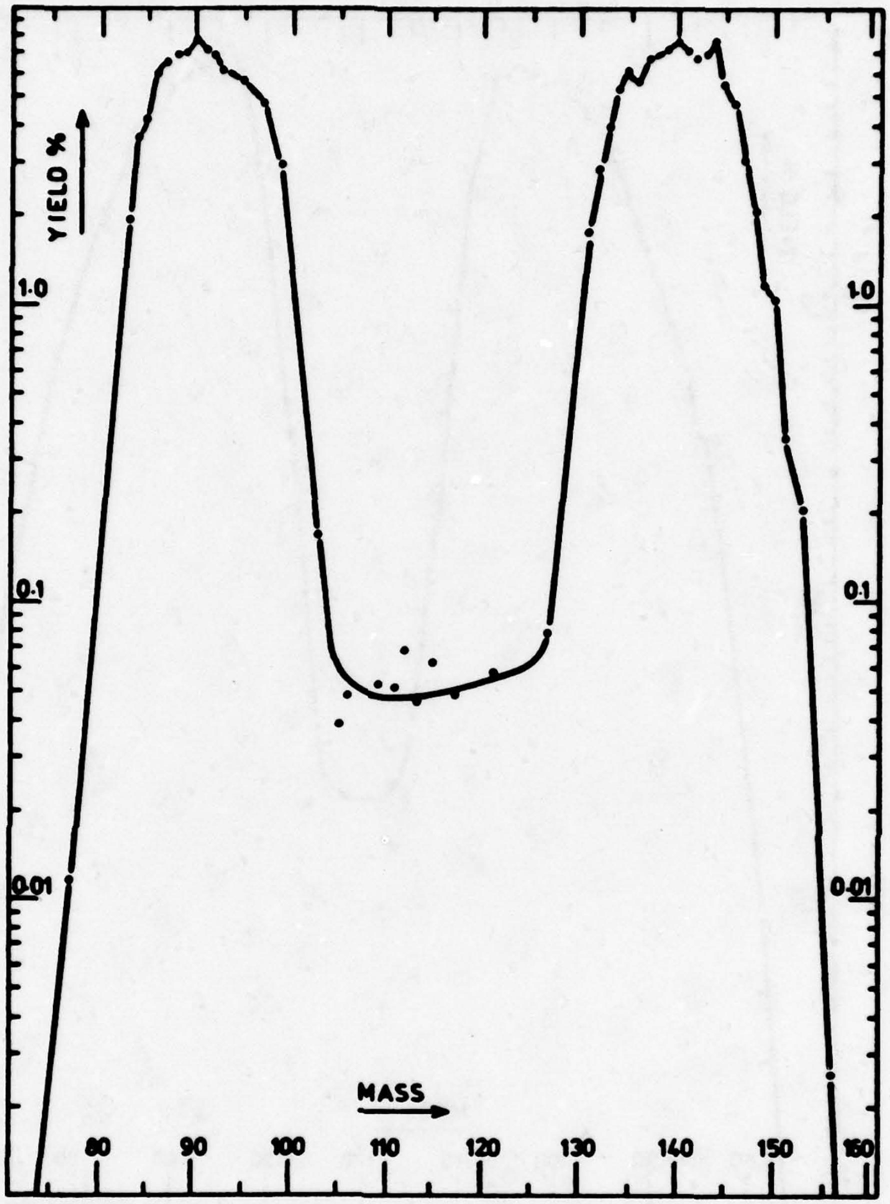
Graphical Data J-1.2. Mass-yield curve for ^{235}U thermal fission. These data were taken from E.A.C. Crouch, "Fission-Product Yields from Neutron-Induced Fission", Atomic Data and Nuclear Data Tables 19, 417-532 (1977).



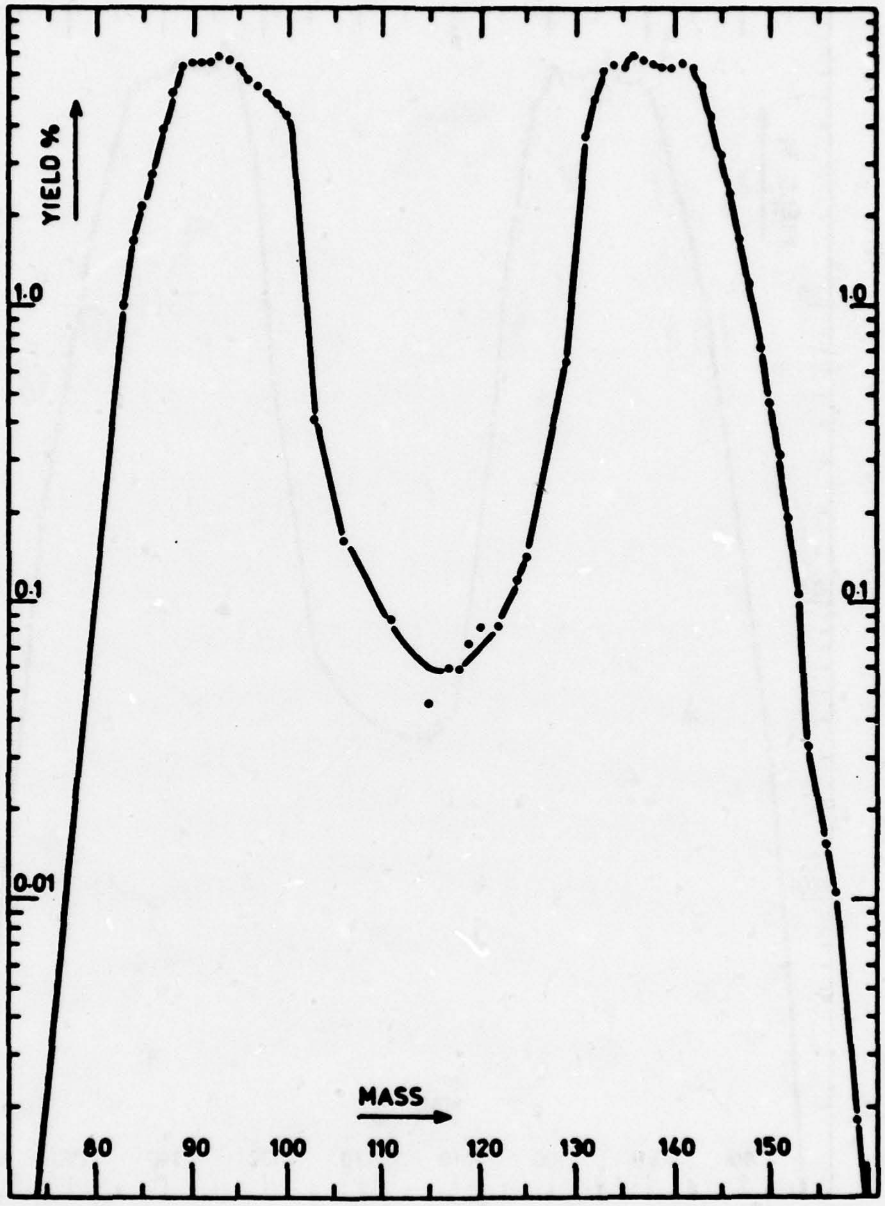
Graphical Data J-1.3. Mass-yield curve for ^{239}Pu thermal fission. These data were taken from E.A.C. Crouch, "Fission-Product Yields from Neutron-Induced Fission", Atomic Data and Nuclear Data Tables 19, 417-532 (1977).



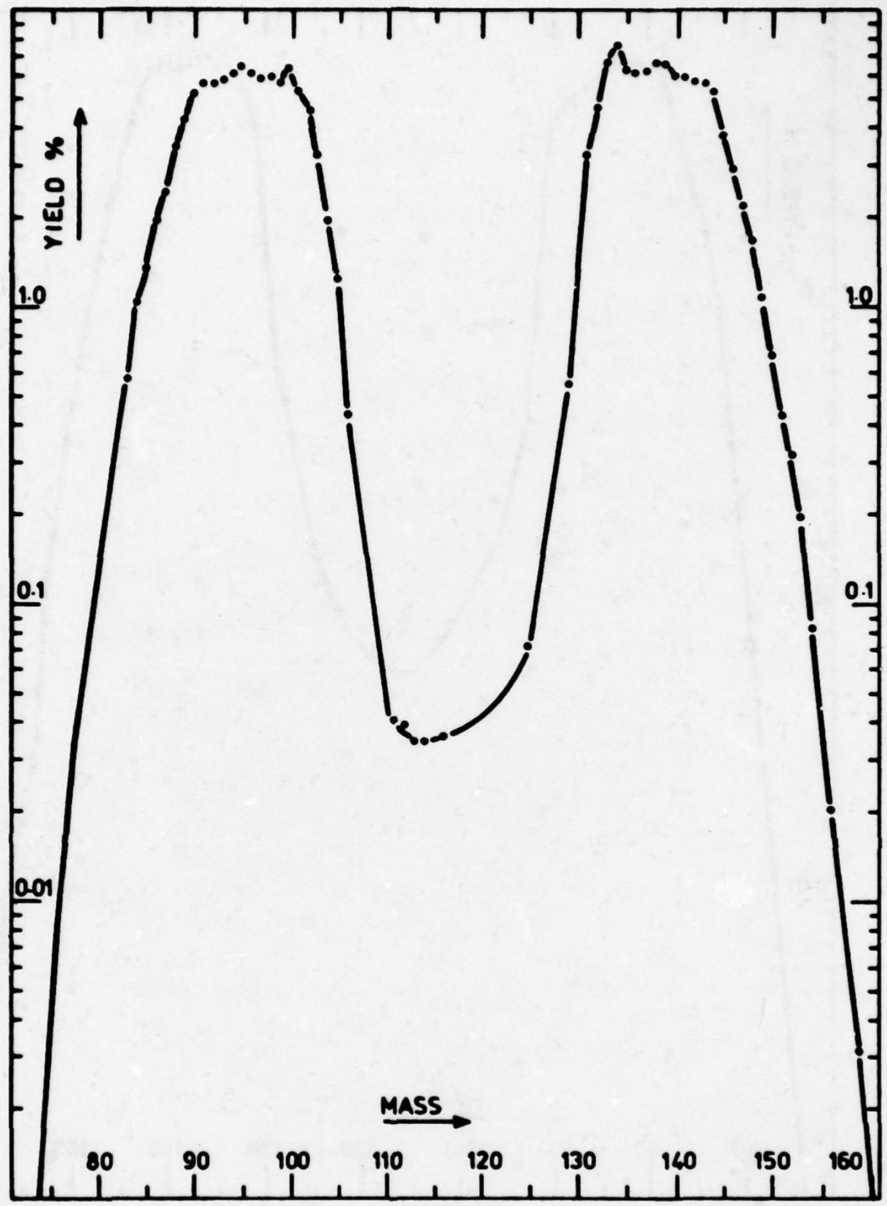
Graphical Data J-1.4. Mass-yield curve for ^{241}Pu thermal fission. These data were taken from E.A.C. Crouch, "Fission-Product Yields from Neutron-Induced Fission", Atomic Data and Nuclear Data Tables 19, 417-532 (1977).



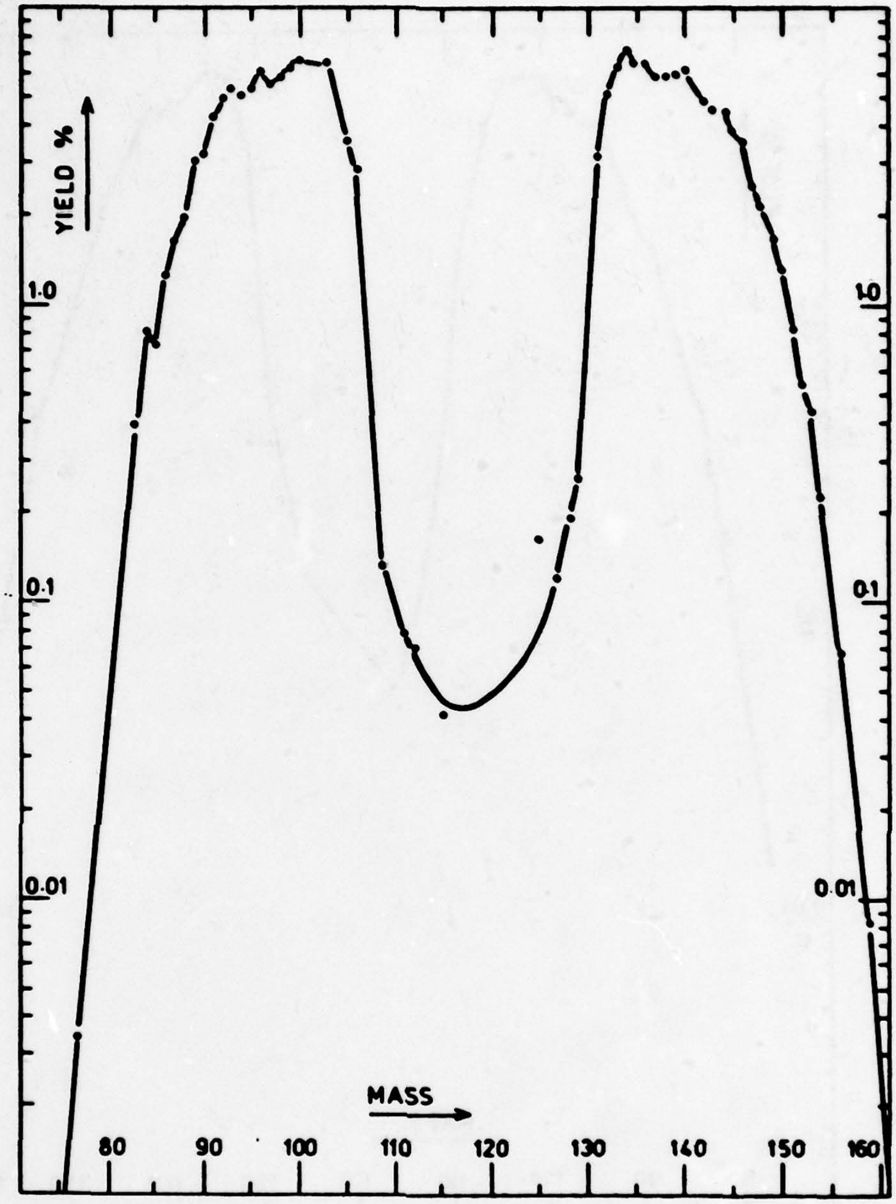
Graphical Data J-1.5. Mass-yield curve for ^{232}Th fast fission. These data were taken from E.A.C. Crouch, "Fission-Product Yields from Neutron-Induced Fission", Atomic Data and Nuclear Data Tables 19, 417-532 (1977).



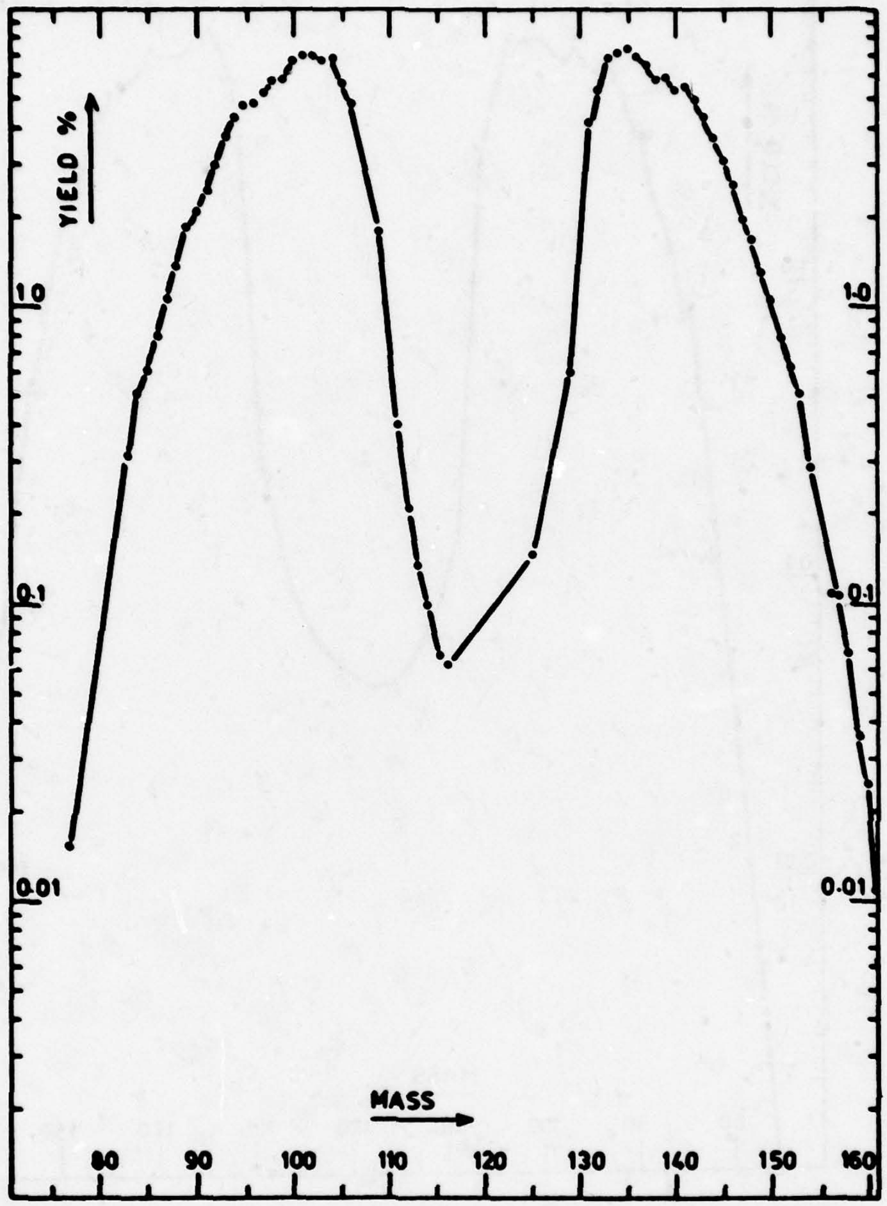
Graphical Data J-1.6. Mass-yield curve for ^{233}U fast fission. These data were taken from E.A.C. Crouch, "Fission-Product Yields from Neutron-Induced Fission", Atomic Data and Nuclear Data Tables <u>19</u>, 417-532 (1977).



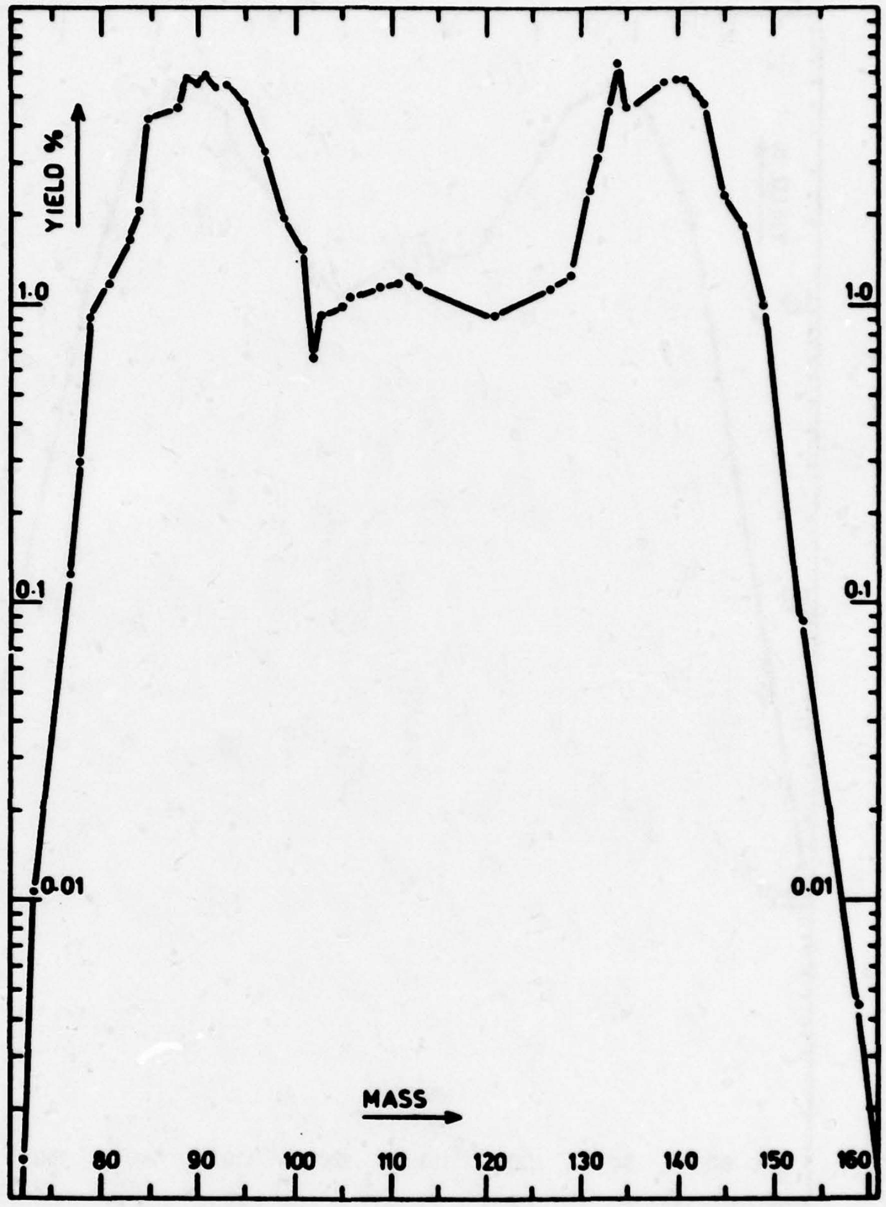
Graphical Data J-1.7. Mass-yield curve for ^{235}U fast fission. These data were taken from E.A.C. Crouch, "Fission-Product Yields from Neutron-Induced Fission", Atomic Data and Nuclear Data Tables 19, 417-532 (1977).



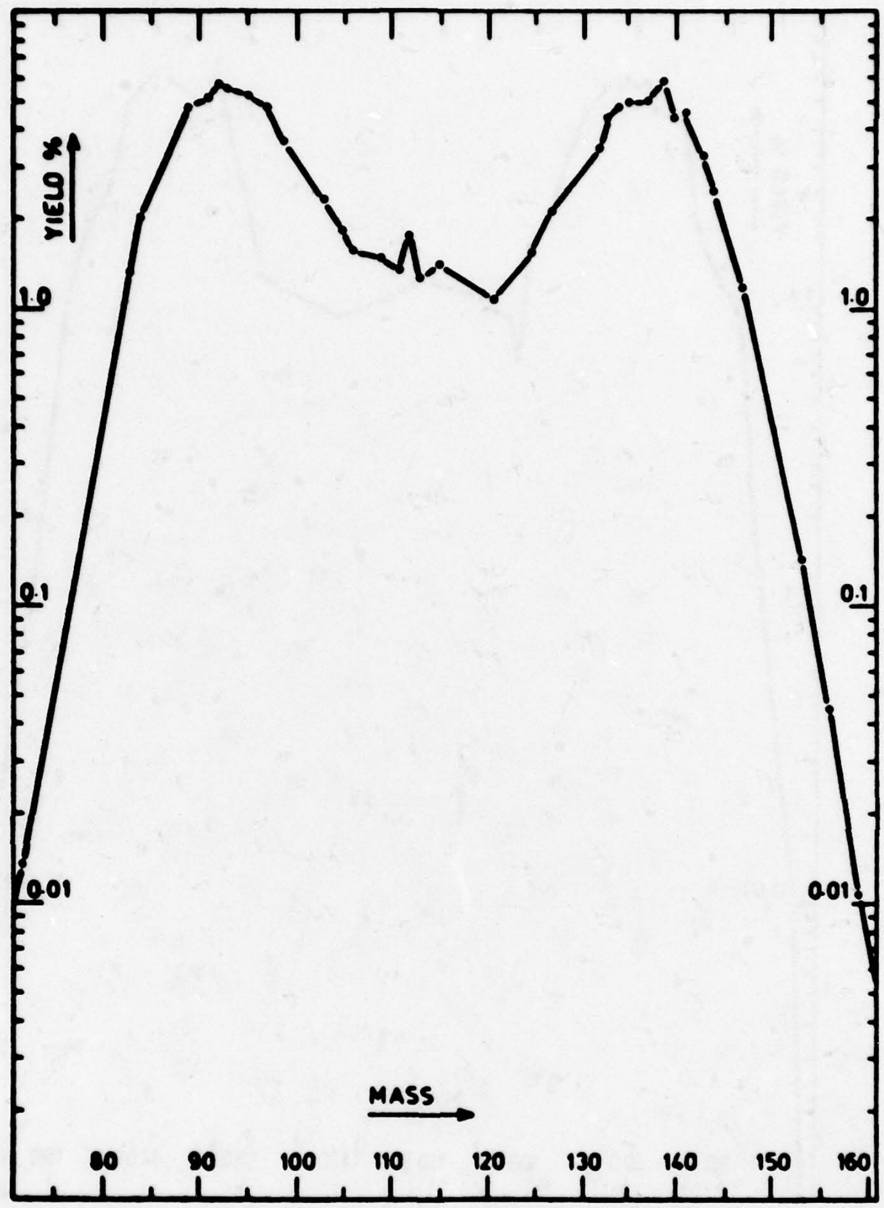
Graphical Data J-1.8. Mass-yield curve for ^{238}U fast fission. These data were taken from E.A.C. Crouch, "Fission-Product Yields from Neutron-Induced Fission", Atomic Data and Nuclear Data Tables 19, 417-532 (1977).



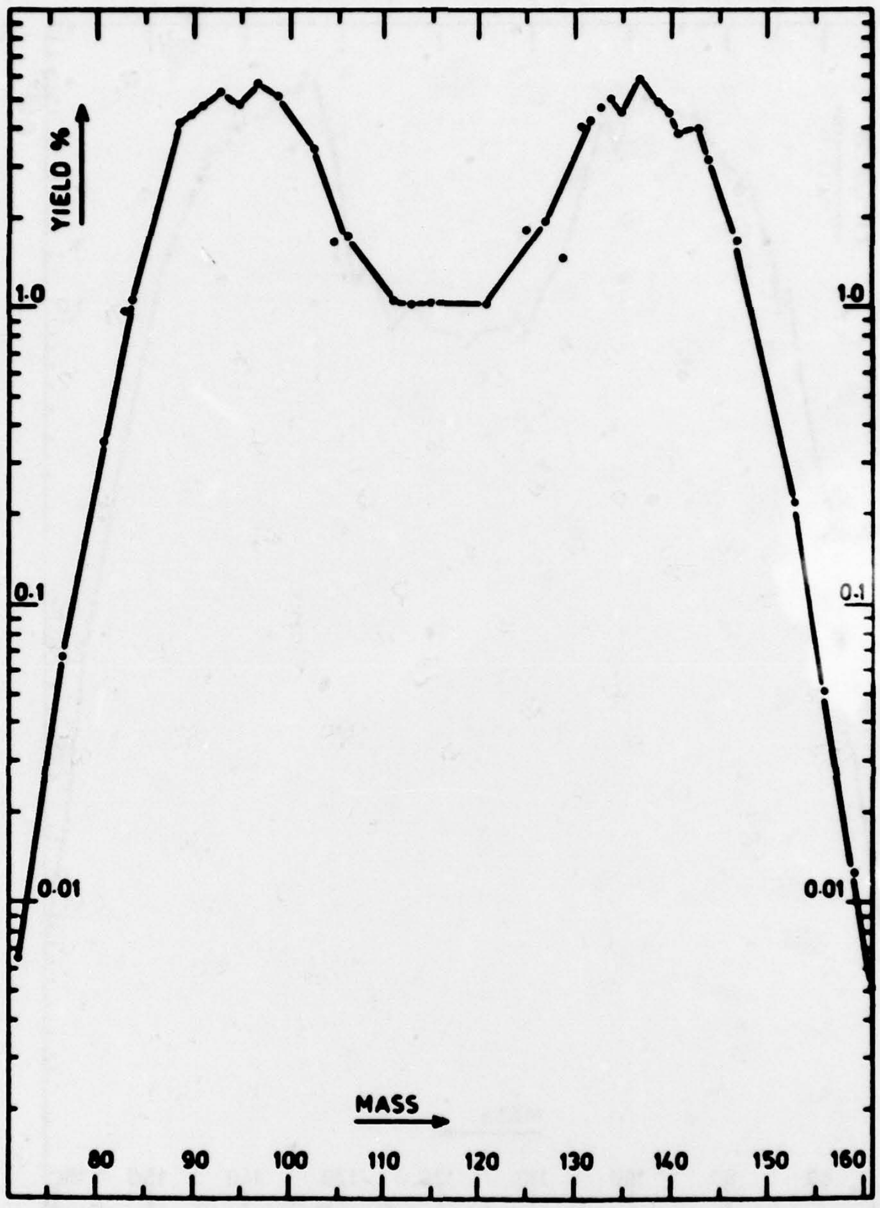
Graphical Data J-1.9. Mass-yield curve for ^{239}Pu fast fission. These data were taken from E.A.C. Crouch, "Fission-Product Yields from Neutron-Induced Fission", Atomic Data and Nuclear Data Tables 19, 417-532 (1977).



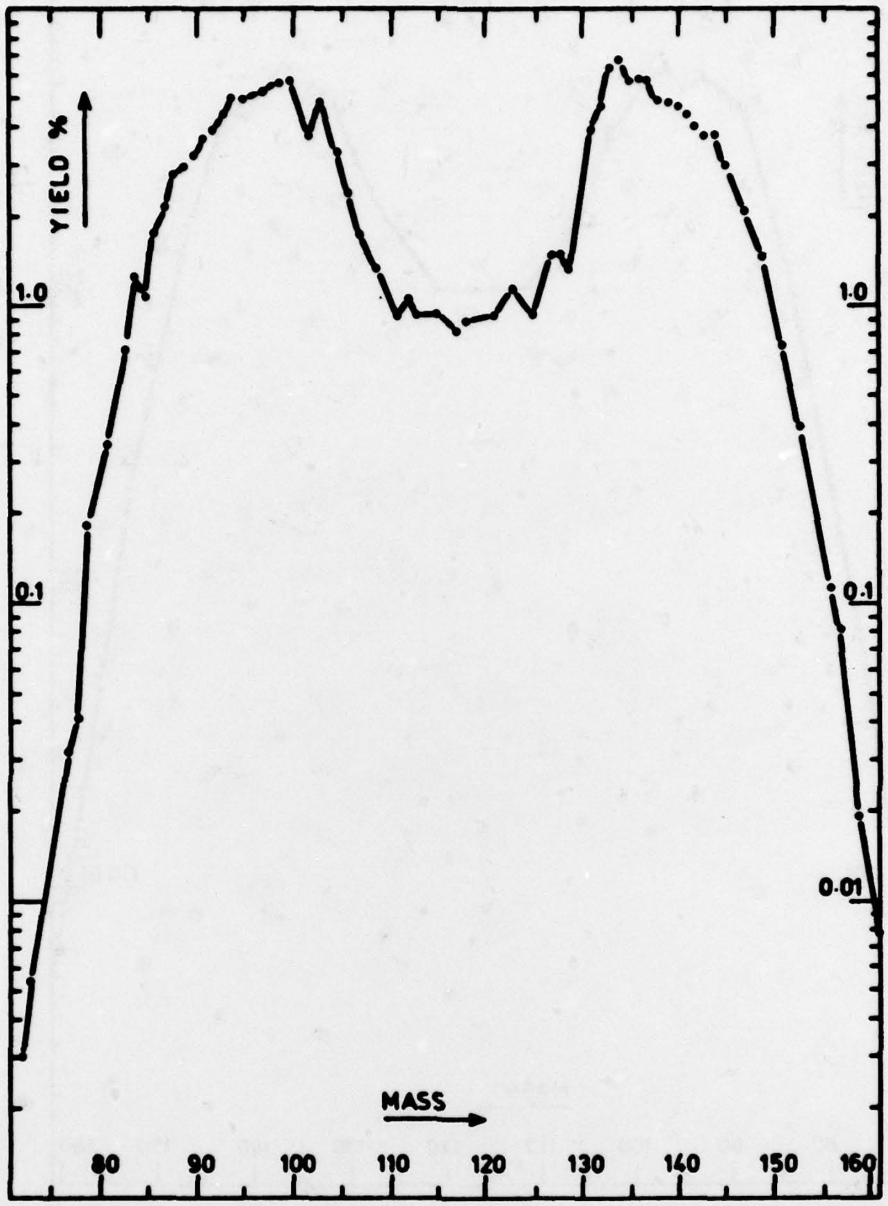
Graphical Data J-1.10. Mass-yield curve for ^{232}Th 14 Mev fission. These data were taken from E.A.C. Crouch, "Fission-Product Yields from Neutron-Induced Fission", Atomic Data and Nuclear Data Tables 19, 417-532 (1977).



Graphical Data J-1.11. Mass-yield curve for ^{233}U 14 MeV fission. These data were taken from E.A.C. Crouch, "Fission-Product Yields from Neutron-Induced Fission", Atomic Data and Nuclear Data Tables 19, 417-532 (1977).



Graphical Data J-1.12. Mass-yield curve for 14 MeV fission of ^{235}U. These data were taken from E.A.C. Crouch, "Fission-Product Yields from Neutron-Induced Fission", Atomic Data and Nuclear Data Tables 19, 417-532 (1977).



Graphical Data J-1.13. Mass-yield curve for 14 MeV fission of ^{238}U. These data were taken from E.A.C. Crouch, "Fission-Product Yields from Neutron-Induced Fission", Atomic Data and Nuclear Data Tables 19, 417-532 (1977).

J-2. GAMMA-RAY AND HALF-LIFE DATA FOR THE FISSION PRODUCTS

Reference: J. Blachot and C. Fiche, Atomic Data and Nuclear Data Tables 20, 241-310 (1977).

ABSTRACT

Presented here are gamma-ray and half-life data for the fission products. The first table lists the energies and intensities of up to 5 of the more abundant gamma rays for each fission product. The second table lists gamma rays in order of increasing energy. The first section of this table covers nuclides with half-life less than one hour. The second section covers nuclides with half-life greater than one hour. Each listing consists of gamma-ray energy, intensity, and half-life. The third table lists all the fission products in order of increasing mass. Data for each nuclide include half-life, uncertainty and reference key for half-life, number of gamma rays, reference key for gamma data, total gamma-decay energy (including internal-conversion energy), and internal-conversion energy expressed as fraction of total gamma-decay energy.

References available through January 1977 have been covered.

J-3. OTHER DATA ON NEUTRON-INDUCED FISSION

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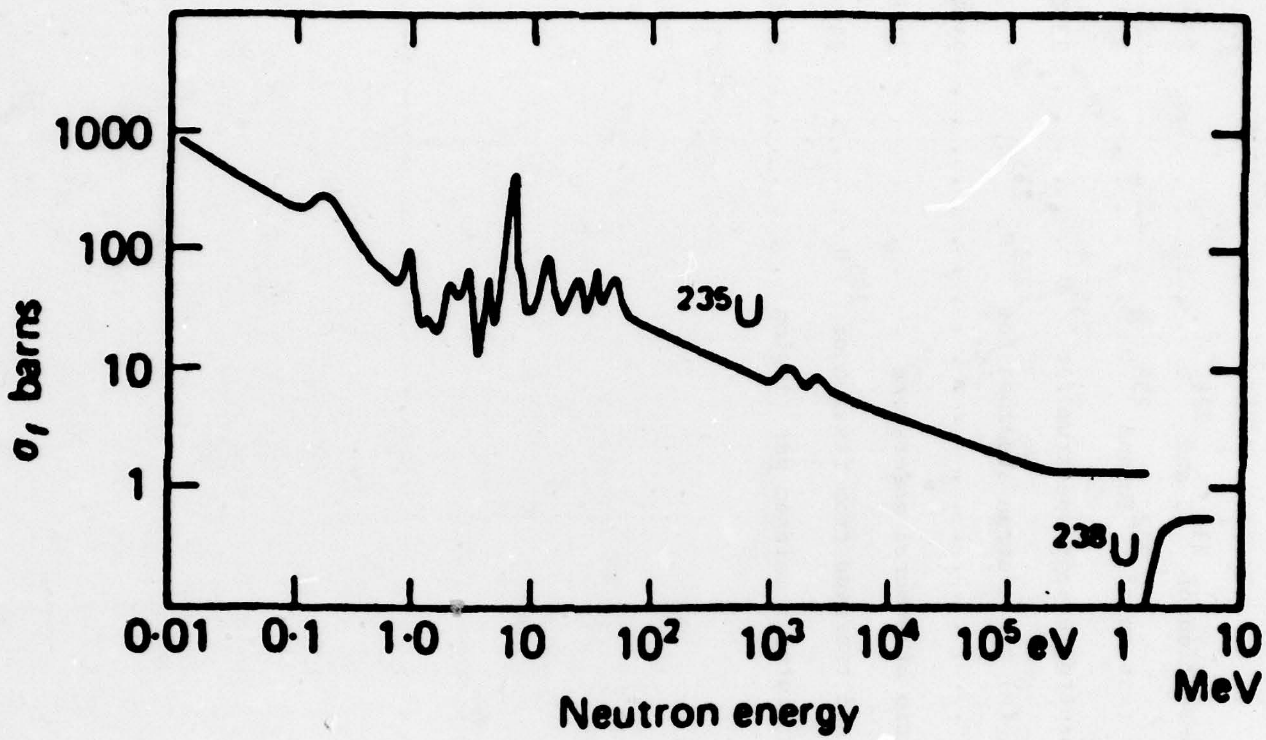
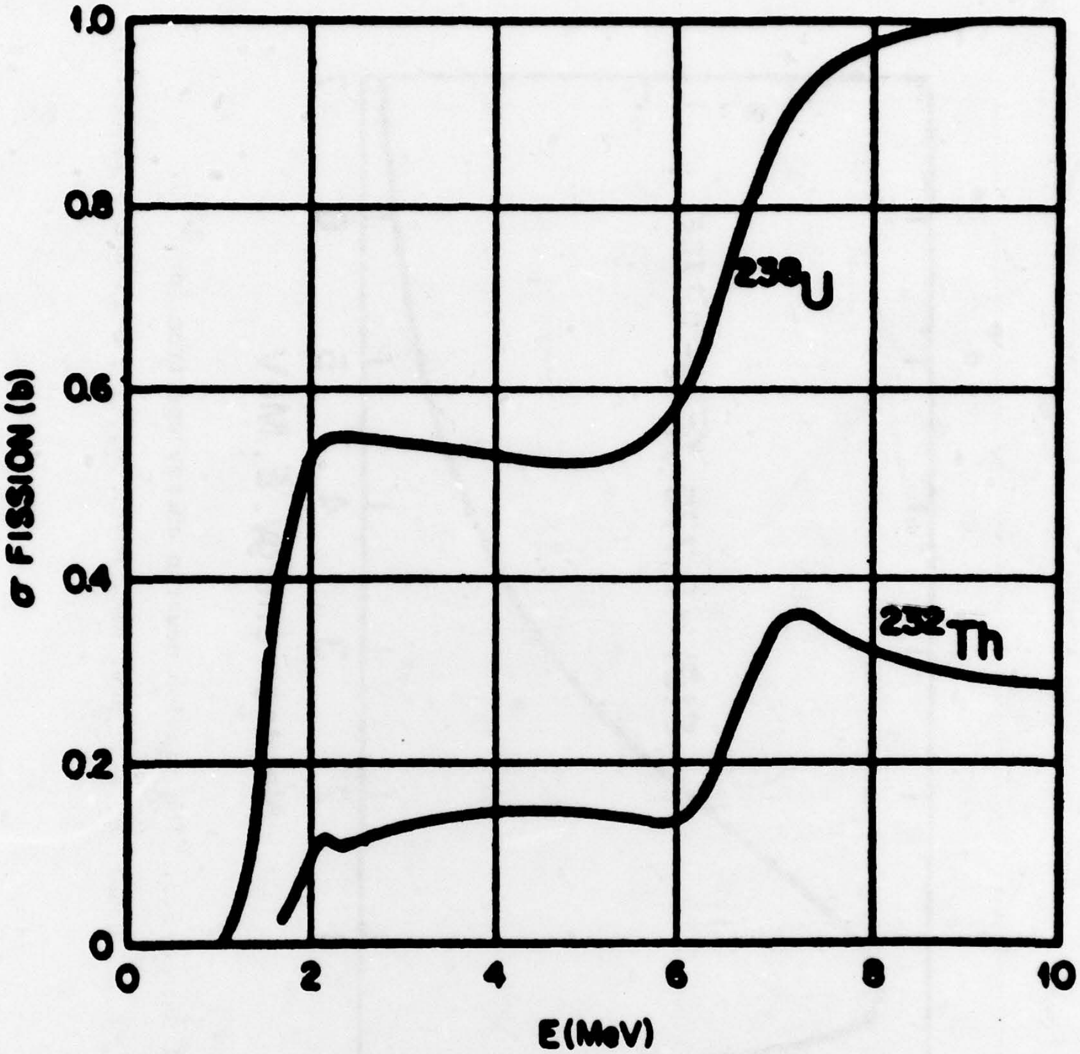


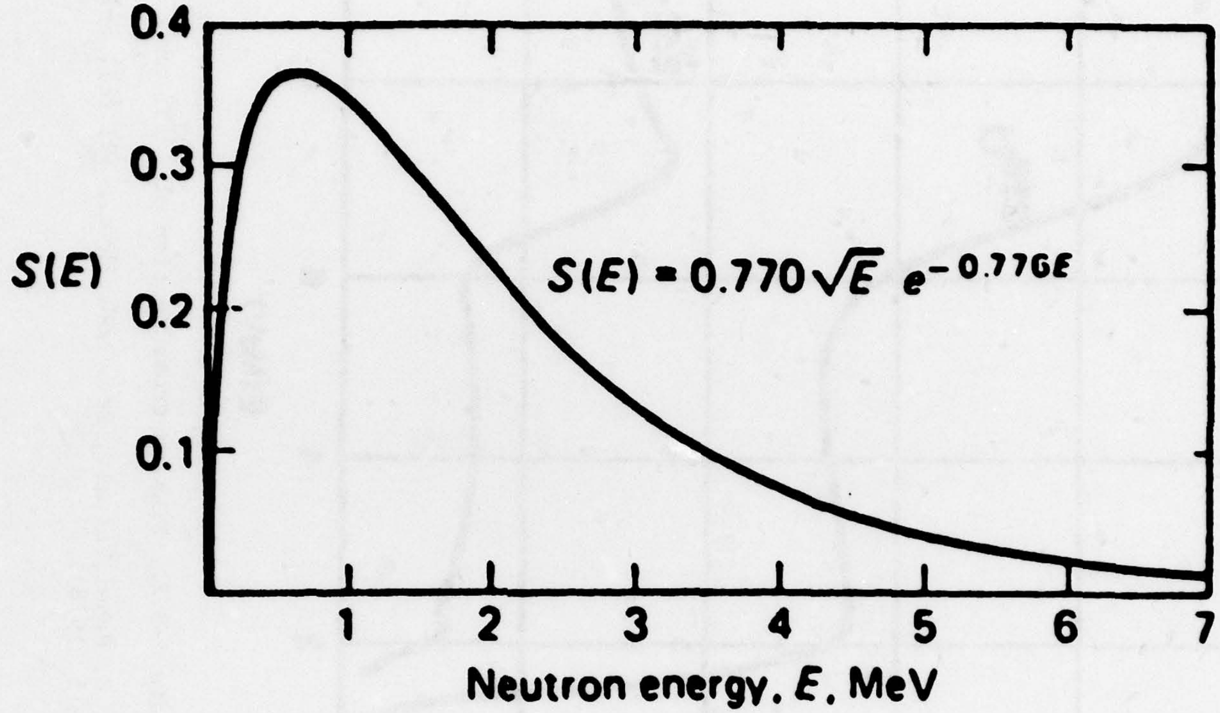
Graphical Data J-3.1. Fission cross-section of ^{235}U and ^{238}U.

Reference: L. C. Hebel, et al., Rev. Mod. Phys., 50, (1), S-13 and S-15 (1978).



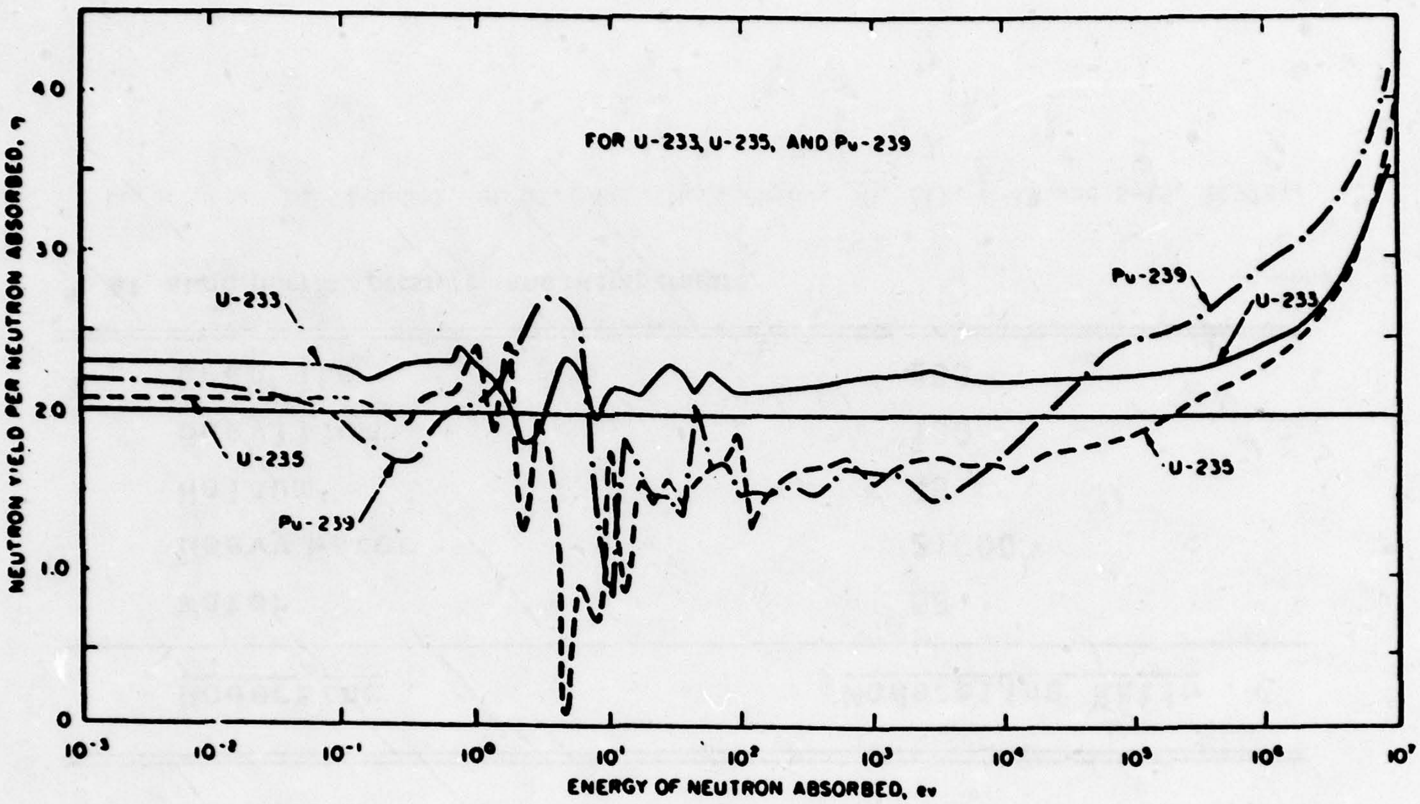
Graphical Data J-3.2. Fission cross section of ^{232}Th and ^{238}U.

Reference: L. C. Hebel, et al., Rev. Mod. Phys., 50, (1), S-13 and S-15 (1978).



Graphical Data J-3.3. The fission neutron energy spectrum for ^{235}U.

Reference: L. C. Hebel, et al., Rev. Mod. Phys., 50, (1), S-13 and S-15 (1978).



Graphical Data J-3.4. Neutron yield (η) per neutron absorbed for ^{233}U, ^{235}U, and ^{239}Pu.

Reference: L. C. Hebel, et al., Rev. Mod. Phys., 50, (1) S-13 and S-15 (1978).

Tabular Data J-3.6. Moderating ratio of several moderators.

Moderator	Moderating Ratio
Water	58
Heavy Water	21000
Helium[a]	45
Beryllium	130
Graphite	200

[a] At atmospheric pressure and temperature.

Reference: L. C. Hebel, et al., Rev. Mod. Phys., 50, (1), S-13 and S-15, (1978).

Tabular Data J-3.6. End products and energies from fission of ^{235}U.

End-product	Emitted Energy (MeV)
Fission products	168
Fission neutrons	5
Prompt γ radiation	7
Fission product decay	
β radiation	8
γ radiation	7
neutrinos	12
Capture γ radiation	5
Total	212

Reference: L. C. Hebel, et al., Rev. Mod. Phys., 50, (1), S-13 and S-15 (1978).

Tabular Data J-3.7. The number of neutrons emitted per fission.

Isotope	Incident neutron energy	Number of neutrons emitted per fission
^{235}U	0.025 ev	2.44
	1 MeV	2.50
^{239}Pu	0.025 eV	2.87
	1 MeV	3.02
^{233}U	0.025 eV	2.48
	1 MeV	2.55
^{232}Th	1.5 MeV	2.12
^{238}U	1.1 MeV	2.46

Reference: L. C. Hebel, et al., Rev. Mod. Phys., 50, (1), S-13 and S-15 (1978).

J-4. REACTIONS OF THERMAL NEUTRONS WITH LIGHT NUCLIDES

$$B^{10} + n \rightarrow \alpha + Li^{7} + 2.3\ \text{MeV}$$

$$(\alpha:\ 1.46\ \text{MeV},\ Li^{7}:\ 0.84\ \text{MeV})$$

$$\sigma_{thermal} = (3837 \pm 9)\ \text{barns}$$

$$He^{3} + n \rightarrow p + T + 0.76\ \text{MeV}$$

$$(p:\ 0.57\ \text{MeV},\ T:\ 0.19\ \text{MeV}$$

$$\sigma_{thermal} = (5327 \pm 10)\ \text{barns}$$

Reference: G. Erdtmann, "Neutron Activation Tables", Verlag Chemie, Weinheim, New York (1976).

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